9

ENVIRONMENTAL FACTORS IN ARCHAEOLOGICAL SITE LOCATIONS

PICEANCE BASIN, COLORADO

JAMES GRADY

BUREAU OF
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CULTURAL
RESOURCES
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ENVIRONMENTAL FACTORS
IN ARCHAEOLOGICAL
SITE LOCATIONS

by

JAMES GRADY

Colorado State Office
Bureau of Land Management
1980

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FOREWORD

Effective management of the nation's cultural resources requires the Bureau of Land Management to be aware of and encourage novel approaches to solving large scale archeological problems as they occur on public land. Effective management also makes it imperative that new methods of data acquisitions and synthesizing complex data into understandable and comprehensive predictive models be developed. Although specifically concerned with factors that influenced aboriginal occupations of the Piceance Basin in northwestern Colorado, this study is just such an approach.

It provides a plausible reconstruction of a life style based on seasonal movement of people to exploit resources whose location is determined by altitude.

Of particular interest in this study is the use of modern environmental data, both floral and faunal, developed on public lands as a data base. This data coupled with the use of aerial photography means that modern data and technology can successfully be brought to bear on complex archeological problems involving large geographical regions.

I am pleased to present this publication, the ninth in our cultural resource series, to both the public and professional communities.

DALE R. ANDRUS
State Director
Colorado
Bureau of Land Management

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FRONTSPIECE AFTER JENNINGS
"PREHISTORY OF NORTH AMERICA"

ACKNOWLEDGMENTS

Literally dozens of people have been involved, each contributing time, knowledge, talent and support, to bring this dissertation to fruition. While it is impossible to mention and thank everyone who has contributed to this work, this does not mean their contributions have been overlooked; they certainly have my sincere thanks.

I should also like to thank my dissertation committee Drs. James J. Hester, David A. Breternitz, Frank W. Eddy, Donald D. MacPhail, and Joe Ben Wheat for their patience, help and encouragement. I want to especially thank Dr. James Hester for his critical comments, his stimulation, and above all, his friendship; to him I owe a debt that can never be repaid.

To single out any one or two individuals from Cambridge University is to do a disservice to many, but certainly the thought-provoking discussions I was fortunate enough to have with both Eric S. Higgs and David L. Clarke have influenced my thinking on economic theories and intellectual development. Their tragic and untimely deaths are a real loss to archaeologists throughout the world.

I am also most grateful for the kind cooperation and generosity extended to me by Dr. Calvin H. Jennings

of Colorado State University and Dr. Alan P. Olson of Denver University. I must also thank Dr. H. M. Wormington for the use of her extensive library and Dr. Omer C. Stewart for sharing with me his vast knowledge of the Ute Indian.

A special thanks is due to Hartley H. Bloomfield, Jr. and his wife, Lynn, for their generous help and cooperation. Without Hartley's detailed and intimate knowledge of the basin, completion of this dissertation would have been long delayed. Further, mention must be made of the Rangely-Meeker Chapter of the Colorado Archaeological Society who generously donated time, tools, and talent in the excavation of the Square "S" rockshelter during the summer of 1976. This chapter fulfills the best definition of "Amateur" and Hartley Bloomfield deserves a vote of thanks from the citizens of northwestern Colorado for the role he has played in its formation.

A special thanks is also due to Robert Hardwick for his generous donation of materials and flying time out of his busy schedule. Thanks is also due to Abbe Currant of Laramie, Wyoming for the artistry of her vegetation maps and to Fran Snow for typing the manuscript.

Most of all I want to thank my wife, Anne, and my family for their support, encouragement, and tolerance when reason dictated otherwise.

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CHAPTER I

INTRODUCTION AND PROBLEM STATEMENT

Interest in how and why man distributed his activities where he did over the landscape is a comparatively recent phenomenon in archaeology. In 1968 Willey identified the total landscape distribution of sites as being the most difficult to comprehend. Part of this difficulty is attributed by Willey (1968:216) to difficulty in defining the size of or the boundaries of the territorial unit under consideration. This is not surprising since conventional definitions of regions are based on similarity. In other words, a boundary can be said to exist when the basic physiography or some other defined characteristic of the landscape changes. As a consequence, we tend to study homogeneous units in which we find similar sorts of sites with similar artifact inventories located in similar settings. This similarity has been used to develop predictive models. Unfortunately, these models retain their validity only as long as the landscape or the region remains unchanged.

In these models similarity of artifact form or style and artifact content is considered to be diagnostic of cultural affiliation. Consequently, changes in artifact style or inventory, either spatially or temporally is equated with culture change. The same arguments can be advanced when dealing with the site. Similar sites in similar settings with similar contents tend to be equated with specific cultures.

Archaeology's inability to cope with macro-patterns of site distribution seems, therefore, to rest on two basic causes: over-dependence on artifact-oriented models of explanation, and an over-dependence on the "site" as a basic unit of study. We are studying macro-problems, as it were, with micro-concepts and data bases.

Selection of concepts and a data base of an appropriate scale should help resolve difficulties encountered when studying site distribution on a large scale. For example, if we change our criteria of regional definition from one of similarity to one of heterogeneity, we can develop models that utilize such ideas as resource seasonality and strategies of exploitation based on complementarity of resources. Obviously, such models tend to be economic models.

The patterns of economic behavior or the economic strategies employed by man are his principal tools in coping with his environment. As such, models of these strategies may be used to solve large-scale locational problems. It seems reasonable to argue that if stylistic differences in artifact form can be used to define cultural affiliations, then man's most crucial artifact, his economy, should have equal potential. Certainly economic strategies have as much potential as artifacts to establish sequences of cultural change, define cultural boundaries, and to test various hypotheses dealing with the adaptive role of culture.

Site location studies inherently deal with how and why sites are distributed over a landscape. Thus we are in a position to study the interrelationship of site distribution and the various environmental factors, both floral and faunal, that make up a total landscape. This implies that the contemporaneous behavior patterns of animals and the modern distribution of plants and their seasonality can be brought to bear as data bases in solving archaeological problems.

The question of why people locate where they do has also intrigued workers in many other disciplines. Archaeology's interest has centered on how people distribute themselves over the landscape and how and why these distributions change through time. Study by the cultural ecologist of the relationship between location and environmental factors has yielded insights into a very complex cause-and-effect relationship. The interchange of ideas and concepts between the archaeologist and the cultural ecologist has been one of the most stimulating and provocative in anthropology's continuing search for understanding of human behavior. This intra-disciplinary approach is closely paralleled by inter-disciplinary interchange of ideas between geography and anthropology. Unfortunately to date this interchange has tended to be a one-way street with anthropologists and, in particular, archaeologists, borrowing heavily from the geographer. This is not surprising when one considers the fact that the geographer's theoretical concepts and his sophisticated calculus represent the forefront in theoretical thinking on the subject. Each discipline has developed concepts and methods bearing on the problem of human location, and each can benefit from the work, concepts, and ideas current in these complimentary approaches.

Settlement Archaeology

Archaeological work with settlement, *per se*, is a comparatively recent phenomenon. In fact publication in 1953 of Gordon R. Willey's *Prehistoric Settlement Patterns in the Viru Valley, Peru* marks the beginning of archaeological interest in settlement patterns. It provided the first explicit statement dealing with the study of settlement and settlement patterns, which Willey defined as follows:

> The term "settlement pattern" is defined here as the way in which man disposed himself over the landscape on which he lived. It refers to dwellings, to their arrangement, and to the nature and disposition of other buildings pertaining to community life. These settlements reflect the natural environment, the level of technology on which the builders operated, and various institutions of social interaction and control which the culture maintained. Because

> settlement patterns are, to a large extent, directly shaped by widely held cultural needs, they offer a strategic starting point for the functional interpretation of archaeological cultures (Willey 1953: 1).

Willey's work sparked a proliferation of settlement studies, and 1955 and 1956 saw a series of landmark seminars held whose goal was to formulate and consolidate thinking on settlement.

The first in 1955, the "Beardsley Seminar," (1956) attempted to define community patterns based on subsistence and settlement configurations. The second seminar resulted in the publication of _Prehistoric Settlement Patterns in the New World_ (Willey 1956) and brought together a series of papers reflecting diverse opinions and approaches to the problem. On the basis of these opinions Willey noted the following:

1. Settlement offered a meeting ground for archaeology and ethnology, and
2. There was no settlement approach in archaeology, rather "settlement data extends the net of archaeological interest to take in a larger and legitimate part of the record."

By the early 1960's two basic trends had emerged in settlement studies. The first, a descriptive approach, was a continuation of the work of Gordon Willey, while the second approach, an hierarchical approach, had its origins in a paper published in 1958 by Kwang-Chih Chang.

In this paper Chang distinguished between settlement pattern and community pattern:

> Settlement pattern is the manner in which human settlements are arranged over the landscape in relation to physiographic environment," while "community pattern is the manner in which the inhabitants arrange their structures within the community and their communities within the aggregate."

Chang's settlement pattern/community pattern dichotomy is an attempt to separate factors of the natural environment from the socio-cultural milieu. Community pattern (micro pattern) consists of the locus of residence and is reserved for the study of socio-cultural phenomena. Settlement pattern (macro pattern) deals with zonal, regional, areal, or widespread distribution of settlement over the landscape; consequently, the tendency is to view settlement pattern in an ecological context.

In 1968 Trigger (1968:79) established three levels of organization: the individual house, the site or community, and the total landscape distribution and added a new factor, the determinant, defined as "those classes of factors that interact with each other to produce spatial configurations of a social group" (1968: 53). Struever (1968:287) also proposed a three-fold hierarchy for structured relationships. His activity area and areas of social distinction are each felt to have inventories of spatially defined archaeological assemblages; consequently, they become the basic building block of his third hierarchical level, the settlement type.

Struever further stresses the interrelationship of these levels as parts of a systemic structure. Therefore, changes in environment should be reflected by changes within the cultural sub-system. Two things stand out in Struever's arguments: the systemic nature of the phenomena of settlement, and the possibility for the study of process once we group the interfaces of the sub-systems within the total system.

Willey (1968), in commenting on Trigger's article, notes that the three levels of primary observation become more difficult to study as we move from small to large. The total landscape is, according to Willey, the most difficult of all to comprehend. It can only be brought into focus after considerable archaeological research has been carried out in a zone, region, or area, and after conclusions have been reached about size and borders of the territorial unit (Willey 1968:216).

In general it would seem there are four main aspects of settlement archaeology that clearly stand out. The study of settlement can be descriptive, it can be studied at different levels of organization, it can be studied as a system with sub-systems, and finally, it can be studied as a process.

Ecological Approaches to Location

The above approaches to settlement tend to be internalized. Ecological approaches tend to be externalized as the ecological perspective is essentially an outward-looking approach. In other words the setting of the site is considered to be as important as the site itself.

An ecological approach to the study of culture implies an interrelationship between the environment and culture. Thinking on the subject has developed two points of view. The first point of view tends to see the environment as a limiting factor. As early as 1938 Steward noted:

> Many modes of behavior were, of course, partly or entirely non-economic, but the latitude permitted them was often established by the framework of ecology (1938:2).

By 1955 Steward had incorporated the arguments of Hawley in that:

> The weight of evidence forces the conclusion that the physical environment exerts but a permissive and limiting effect (quoted in Steward 1955:34).

Ecological arguments have their origins in the rejection of the "environmental deterministic" arguments of Huntington and Semple in the early 1920's. This "permissive and limiting" argument of Steward underlies several general theories. For example, Meggars (1954) proposed a deterministic theory about the inhibiting effects of tropical low-land forests, and Wittfogel (1955) views the rise of despotic states as a need to control large scale irrigation projects in semi-arid regions.

In 1964 M. D. Coe and K. V. Flannery rejected the deterministic role of the major biome and instead concentrated attention on the role of the "microenvironment." Steward in 1938 had already provided the general model of microenvironmental exploitation. Steward's study showed that the Great Basin people seasonally exploited both vertically and horizontally differentiated sets of environments (Steward 1938). This model underlies much current thinking on hunter/gatherers (Service 1966, Lee and Devore 1968, Damas 1969) and has served as the model of procurement in the Tehuacan Valley Project (MacNeish 1964). Testing and confirmation of this model has been accomplished in the Reese River Ecological Project (Thomas 1972, 1973; Williams, et al. 1973).

It is within microenvironments that men have consistently found the critical resources that enable them to survive. Yet while most site reports contain both an ecological and subsistence statement, little effort has been made to relate site location to specific environmental factors. In most cases the ecological statement is a generalized or a zonal description of present environmental conditions, while the subsistence statement is usually inferred from the archaeological inventory, and not from any systematic study of either botanical or zoological remains.

In an attempt to overcome these shortcomings, the Southwestern Anthropological Research Group (SARG) has devised a three-step program to try to tie archaeological sites to environmental factors. This approach focuses on the following:

1. Locating the site as accurately as possible, either through the use of careful mapping techniques or through the use of aerial photography (Plog and Hill 1971).
2. Relating site location to a set of agreed upon environmental factors (landform, drainage and plant community, etc.) through a simple statistical technique (percentage point difference and chi-square).
3. Formulation of an explanatory statement to account for the known distribution of sites.

To date few results have been published and the efficacy of this approach has yet to be proven.

The second point of view is essentially economic in that the environment provides opportunities which man will exploit to maximum economic advantage depending, of course, on the level of available technology. The leading exponents of this point of view are Eric Higgs (1972 and 1975 and with Vita Finzi in 1970) and Graham Clark (1952, 1953, and 1972).

It should not be surprising that these two divergent ecological approaches also offer differing explanations to account for cultural change. The first approach, that of the "permissive and limiting" school, sees cultural change occurring because of changes within the environment. The latter, the economic school, sees change occurring when existing resources are stressed, primarily through overpopulation. Under these circumstances new resources must be added to the existing inventory, or old resources more efficiently exploited, or a combination of both. In either case, environmental change or resource stress, the typical response is the development of new technology and new patterns of behavior to cope with the new environmental conditions.

Despite these divergent approaches, the ecological viewpoint permits study of critical resources within an environmental setting. Consequently, we should be able to gain some insight into the environmental perception of the social groups involved. The following are some of the basic questions that can be posed by this approach: to what degree were resources exploited; were economic opportunities capitalized upon or overlooked; and finally, are environmental or social factors the main factors in the determination of site location.

Geographical Approaches to Location

The influence of geographical thinking and techniques upon archaeological research is a comparatively recent phenomenon. With the 1968 publication of David

Clarke's Analytical Archaeology names like Chorley and Haggett became known to the archaeologist. Certainly Haggett's book Locational Analysis in Human Geography (1965) and the Chorley and Haggett volume Models in Geography (1967) have had major impact on archaeological thinking. A cursory review of geographical literature permits the following observations.

Geographical literature dealing with how people cluster or arrange themselves in the natural world is voluminous. Numerous studies, theoretical models, and sophisticated methodology and calculus capable of dealing with human locational problems has been developed and provides a convenient starting point for archaeologists interested in locational problems. Within this literature, two general trends are discernible. The first is the theoretical approach of current interest to the new generation of geographers, the second considers the problems of plant and market location and is a branch of economic geography.

The theoretical approach has been expounded by Losch (1954) and Isard (1956) and both are an amplification of W. Christaller's 1933 studies of central places in southern Germany. Theoretical studies seek to develop a general theory adequate to explain the main features of spatial distribution.

Theories are developed regarding the nature of ideal distributions. Then evidence is collected to illustrate that reality conforms. This approach centers on what the patterns should be, rather than what they really are. There is an overall goal of building a model which can explain location and subsequent adjustments and from which overall spatial patterns can be derived.

Basic to all theories of location is the concept of the isotropic plain. This plain exhibits no differences from place to place or in any direction. Sites scattered over the plain have only position and occupancy of space as their basic characteristics, and it is possible to go one step further and specify if their distribution is either random or non-random. A state of randomness would, of course, forestall any further interest. Non-randomness implies some sort of functional relationship between elements on the plain. This relationship can be described by the three factors of directional orientation, distance, and connectivity.

Directionality merely asks the question, "Where is element A in relation to element B?" Effectiveness of the functional relationship is dependent upon distance. Since distance between two points is usually viewed as a geodesic, intensity of communication can be described as a property of distance. Communicative intensity can be seen as both proportional in that cost of transport increases as distance increases, and inversely proportional, in that communicative efficiency decreases as distance increases.

It is imperative to remember that distance can only be measured in terms of the process or activity under consideration; consequently, there are differing "types" of distance. Economic distance should be measured in terms of cost, informational distance should be measured in terms of social interaction, migrational distance in terms of intervening opportunity, and geodesic distance in terms of metric scaling.

Connectivity as a concept can be removed from both distance and direction. It implies a relationship between the elements under consideration. A map may be twisted and distorted by transformation introduced by outside factors, but as long as each element retains its relative position, it will retain its connections. Connections need not be a contiguous boundary. They can be a functional association, i.e., flow of goods, people, or communication. These may be quantified, directional relationship specified, and the relationship can be either symmetrical or asymmetrical.

These basic concepts--directionality, distance, connectivity and their concomitant basic assumption, the isotropic plain--make up the basic viewpoint of the theoretical geographer (Nystuen 1968).

In general the geographical approach to location is based on the concept of a population. Population as used here consists of items or elements that conform to a given definition and which may be assigned a definite location in space (Duncan et al. 1961:21). Since each element has a unique location, the aggregate of individual locations is defined as the distribution. The central problem of locational studies is to describe and explain the significant features of this distribution (Duncan et al. 1961:21).

It could be used to explain the concentration of a population within specific ecological zones and to explain why specific zones are avoided. Further, assuming our concern is with a "population" that is exploiting a series of specific resources, the question might be posed--which of two or more resources is more likely to be exploited and why? Since we are dealing with archaeological sites, we might rephrase the question and ask--which types of archaeological sites are located where and why?

Once we have distinguished parts of the population we can then ask questions about its structure. Structure deals with or suggests a pattern of interrelationships among members of a population (Duncan et al. 1961: 22). (See Hodder's work, 1972, on Romano-British settlement patterns as an example.)

There are, of course, problems from which all theories of general equilibrium suffer. First, theories tend to be formulated in mathematical and algebraic terms which require a considerable degree of expertise for comprehension. Consequently, availability of theory is restricted to experts. Second, mathematical models and mathematical expressions of data require a high degree of abstraction; therefore, some assumptions may be dubious. Finally, factors to which enumeration cannot be assigned are ignored. It is impossible to take into account all phenomena and "exceptions" always occur. Therefore, any general theory is unreal when compared to the real world.

In spite of these problems there are advantages to abstract systems. They offer simplicity and clarity since the elements possess only those properties explicitly assigned to them. In the real world, behavior is often due to causes so involved they cannot be traced. Abstract systems aid in generalizations and abstract concepts are usually regular in nature; consequently, factor loading can approximate the distortions found in reality and the effect of multiple factors can be illustrated.

Contrary to the theoretical approach is the approach to the problem of location developed by economists and economic geographers. These approaches have been set forth by Greenhut (1956) and Weber (1957). They focus their efforts on the problem of industrial plant location. The object of these studies is the determination and examination of all factors which have influenced or determined plant location. Location thus becomes a decision-making process where alternative locations are weighed as to desirability in terms of minimizing cost while maximizing profits (Chisholm 1968).

In contrast to the theoretical approach conclusions derived from plant location studies are specific to the particular firm under consideration and, as a rule, do not have any general value unless the particular firm is representative of many similar firms, or as enough results can be obtained to form an inductively derived generalization bearing on plant location.

If we can assume that the location of an archaeological site can be considered to be the result of a decision or a series of decisions designed to minimize effort while maximizing some desired return (mini-max strategy, Clarke 1968), this approach could possibly provide a method of linking archaeological sites to their respective resource bases.

Unfortunately for the archaeologist, most plant location studies performed by economists are based on cost and market variables, all of which are easily quantifiable and which lend themselves to mathematical manipulation. For the archaeologist to use these highly developed techniques, he too will have to be able to quantify resource and transport cost and relate these to some form of market variable (an expression of need in terms of cost).

Archaeology in general has not made extensive use of the ideas and methods of the theoretical geographer. Yet the use of the Christoller and Losch models (i.e., hexagonal territorial polygons as the result of maximum packing of circular territories) has produced lattices that possibly define territory served by Iron Age Oppida in Britain (see the various Ordnance Survey publications dealing with Iron Age Cornwall and Iron Age Kent and Sussex). A similar model has been applied to Romano-British settlement patterns with interesting results (Hodder 1972). Hodder was able to determine that the Roman settlement of lowland Britain closely approximated that predicted by the Christaller/Losch model. Settlement was hierarchically arranged along Christoller's transport principle and centers which could only be identified as "Roman" could by use of this model be assigned an hierarchical position within the total model. Use of the transport principle involves the imposition of the basic model, a regular hexagonal lattice upon the existing known settlement scene and distorting it until a proper fit is achieved (Clarke 1968).

Another method, the Thiessen Polygon method, involves the "building up" of a lattice through the geometrical construction (see Kopec 1963) of polygons or boundaries around known sites. The resulting polygons may possibly indicate the economic catchment area supporting the central site. Shape and size can often be useful in defining anomalies within the existing data base (Hammond 1972).

To date archaeological use of theoretical models seems to have been most successful when dealing with a cultural landscape and entities where hierarchical organization is apparent (Hodder 1972, Hammond 1972) but their usefulness in dealing with hunting and gathering societies seems promising (Hester and Grady 1976). Using such techniques as nearest neighbor analysis and Thiessen polygon construction on a series of Paleo-Indian sites on the Llano Estacado and in the Rio Grande Valley, Hester and Grady were able to provide insights into site territoriality and function, and into the interrelationship between campsites and killsites.

Certainly works such as David Clarke's posthumously published Spatial Archaeology (1977) will further stimulate research into the problems and potential of this approach.

Of all of the approaches described above the SARG approach comes the closest to providing a methodology for studying the nature of the relationship between man and his environment. Unfortunately, little effort has been expended in the implementation of the SARG design, and even less effort has been made in relating site location to specific environmental factors.

The Problem

The problem is to evaluate specific environmental features for their resource potential and to relate archaeological site location to specific environmental settings. Therefore the specific goals of this study are:

1. to identify those environmental features which impinge upon site location decisions.
2. to determine to what degree the impact of these features varies by defined region.
3. to locate within these defined regions those areas characterized by high site density and those areas of low site density and to be able to comment on the probable cause of this inequitable distribution.
4. to integrate these geographically diverse regions into a cohesive whole through the development of a descriptive model of economic behavior.

Since the environmental data used in this study is shown from the modern landscape, a fifth, and rather serendipitous objective, will be to determine to what extent modern environmental data can be used to test propositions dealing with man's relationship to his environment in the past.

In Chapters II and III the study area chosen is described with particular emphasis placed on its resource potential. An environmental model is developed in Chapter IV and specific hypotheses are formulated to facilitate its testing. The specific environmental factors chosen, the rationale for their choice, the nature of the data base, specialized techniques used, and the statistical tests employed in hypothesis testing are described in Chapter V. Chapter VI contains the actual data analysis. In Chapter VII a comparison between ethnographic record and the data analysis is made, and in the last chapter, Chapter VIII, the descriptive models of economic behavior are presented along with the conclusions.

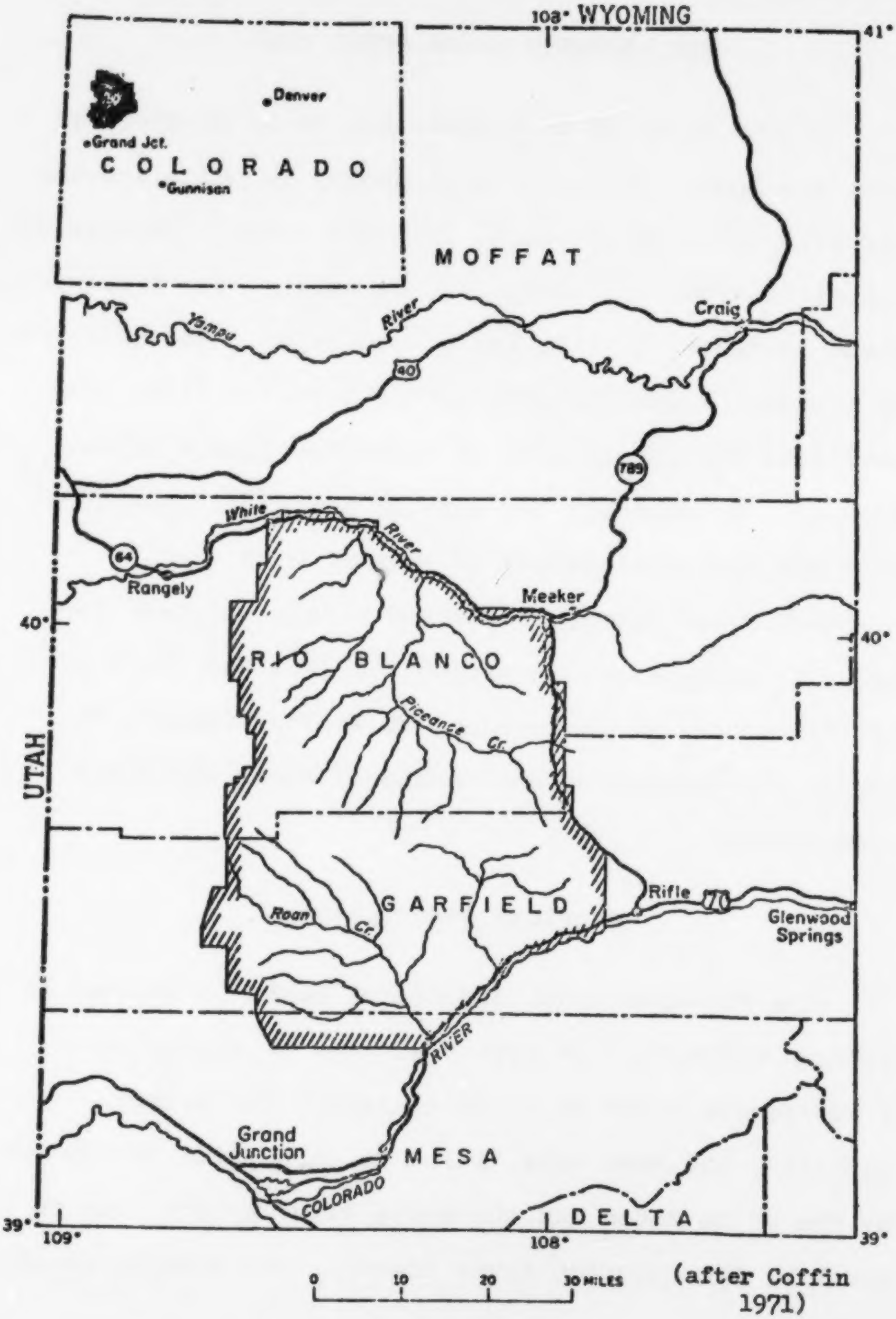
CHAPTER II

THE PICEANCE BASIN STUDY AREA

If the goals of this study are to be reached, an area was needed that was large enough to postulate the reconstruction of an annual economic cycle. Because of its altitudinal and ecological diversity, the Piceance Basin seemed to fulfill these conditions. The presence of a large, migratory deer herd within the Basin also permitted the possibility of reconstructing a mobile economy. A secondary but equally important consideration was the availability of several high quality archaeological surveys conducted within the past few years to provide site distribution data and the availability of aerial photography at scales adequate to permit the mapping of environmental zones and plant communities.

Physical Description

The Piceance Creek structural basin is located in Western Colorado. It covers an area of approximately 1,600 square miles in three counties--Rio Blanco, Garfield, and Mesa (Fig. 1). It is bounded on the north by the White River and the White River uplift, and on the south by the Colorado River trench. The western boundary


108° WYOMING
41°
Denver
Grand Jct.
COLORADO
Gunnison
MOFFAT
Craig
Yampa
River
40
789
White
River
64
Rangely
Meeker
40°
40°
RIO BLANCO
Piceance Cr.
UTAH
Rifle
70
Glenwood Springs
Roan
Cr.
GARFIELD
RIVER
Grand Junction
MESA
COLORADO
DELTA
39°
109°
108°
39°
0
10
20
30 MILES

(after Coffin 1971)

FIGURE 1

LOCATION OF THE PICEANCE BASIN STUDY AREA is delineated in the north by the Cathedral Bluffs, which overlook and act as headwaters for the Douglas/Cathedral Creek drainage complex. The central portion of the western boundary consists of the Douglas Creek Arch. While the southern portion of the boundary is ill defined, the East Salt Creek complex can be used for the sake of convenience. The eastern boundary consists of Flag Creek that flows north into the White River, Government Creek which flows south into the Colorado River, and the Grand Hogback which parallels them to the east (Fig. 1).

The Basin's actual boundaries are a series of rather dramatic escarpments that overlook the White River in the north, the Cathedral Bluffs in the west, and the Roan and Book Cliffs in the south. To the northeast and east there is no effective boundary or line of demarcation to set the Basin apart.

The basin is a northwest tending downwarp whose elevation ranges from about 9,000 feet in the area of the southern river to about 5,700 feet in the White River Basin.

The Divide

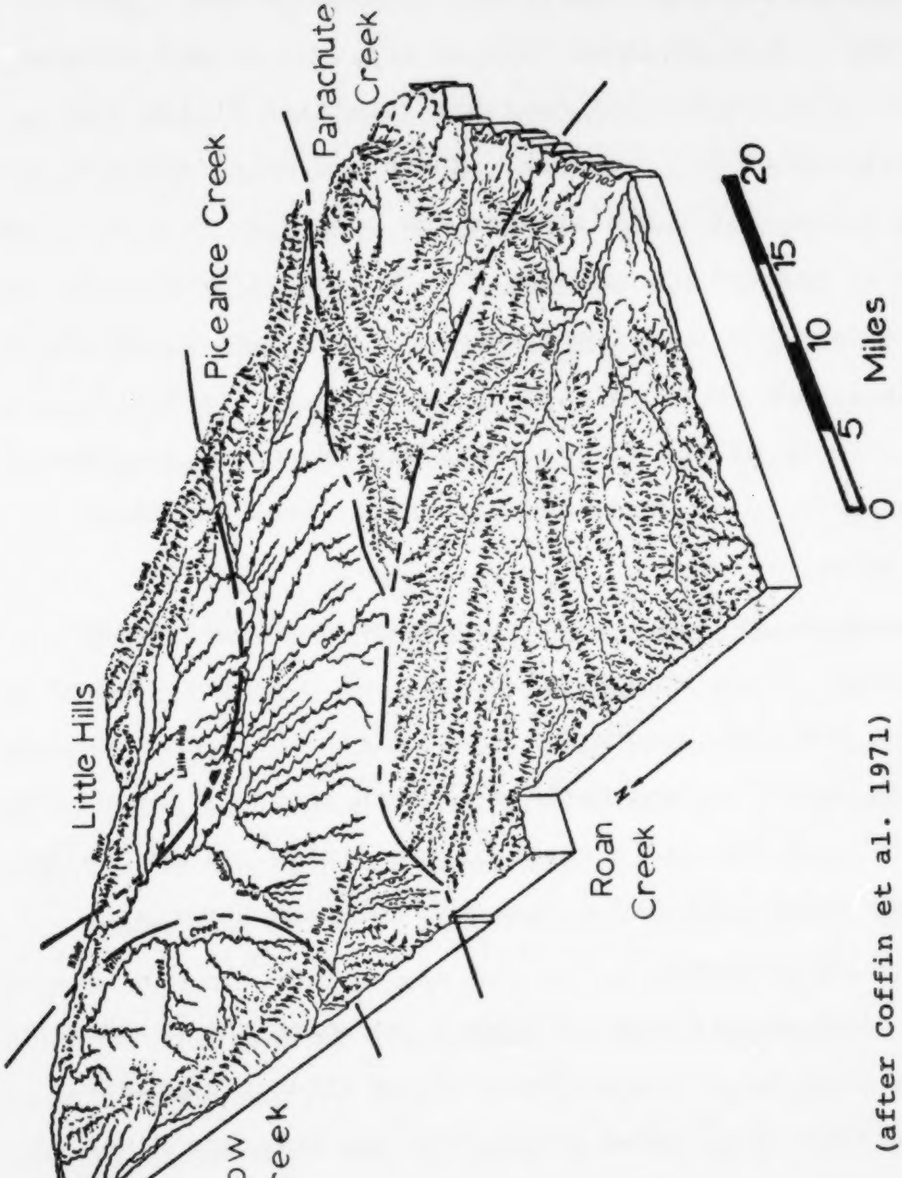
In the southern portion of the structural basin there is a major east-west topographic divide that partitions the basin into two dissimilar units. The northern unit may be further sub-divided into three sub-units: the Yellow Creek drainage, the Piceance Creek drainage, and the Little Hills area (see Fig. 2).

Yellow Creek Drainage: occurs in the northwestern portion of the structural basin. It consists of Yellow Creek and its tributaries that originate in the Cathedral Bluffs area and drain northward into the White River.

Piceance Creek Drainage: lies to the east of Yellow Creek and occupies a central position within the basin. Piceance Creek drains the southernmost portion of the Cathedral Bluffs and the area north of the divide. Piceance Creek, itself, has its origins in the Grand Hogback formation to the east of the structural basin.

Little Hills: this is the area bounded by the Piceance Creek to the west, southwest and south, the White River to the north, and Flag Creek to the east. Streams in the Little Hills area tend to be short and intermittent. They drain for the most part into the Piceance Creek. The Little Hills area is bounded by fairly steep slopes, but once on top the area tends to be relatively flat or slightly rolling.

All of these north flowing streams tend to have flat valley bottoms that may or may not be incised. In general the flat-floored valleys are separated by convex


Little Hills
Piceance Creek
Parachute Creek
Yellow Creek
Roan Creek
N
0
5
10
15
20
Miles

(after Coffin et al. 1971)

FIGURE 2

SUBDIVISIONS OF THE PICEANCE BASIN IN NORTHWESTERN COLORADO or flat-topped ridges (Schum and Olson 1974:7). The valleys tend to be asymmetrical with the north-facing slopes having more and better vegetation and a gentler aspect. Both of these factors are due, in all probability, to the greater moisture retention of the long-surviving winter snowpack. South and west facing slopes and valley sides are steeper and poorly vegetated. These conditions are undoubtedly due to lack of snow pack retention and consequent moisture loss (Schum and Olson 1974:7, and my own winter research in the area).

South of the divide there are two major drainage complexes--Roan Creek and Parachute Creek and their tributaries.

Roan Creek Drainage: occupies the southwestern portion of the structural basin. It consists of Roan Creek and its tributaries that originate in the Douglas Creek uplift on the basin's western boundary and on that portion of the basin south of the divide. This drainage flows south-east and enters the Colorado River at Debeque, Colorado.

Parachute Creek Drainage: occupies the southeasternmost portion of the Piceance Creek structural basin. Parachute Creek flows south into the Colorado River at Grand Valley, Colorado, draining part of the basin south of the divide, part of the plateau area that separates Parachute Creek from the Roan Creek drainage to the west, and that part of the basin known as the Naval Oil Shale Reserve.

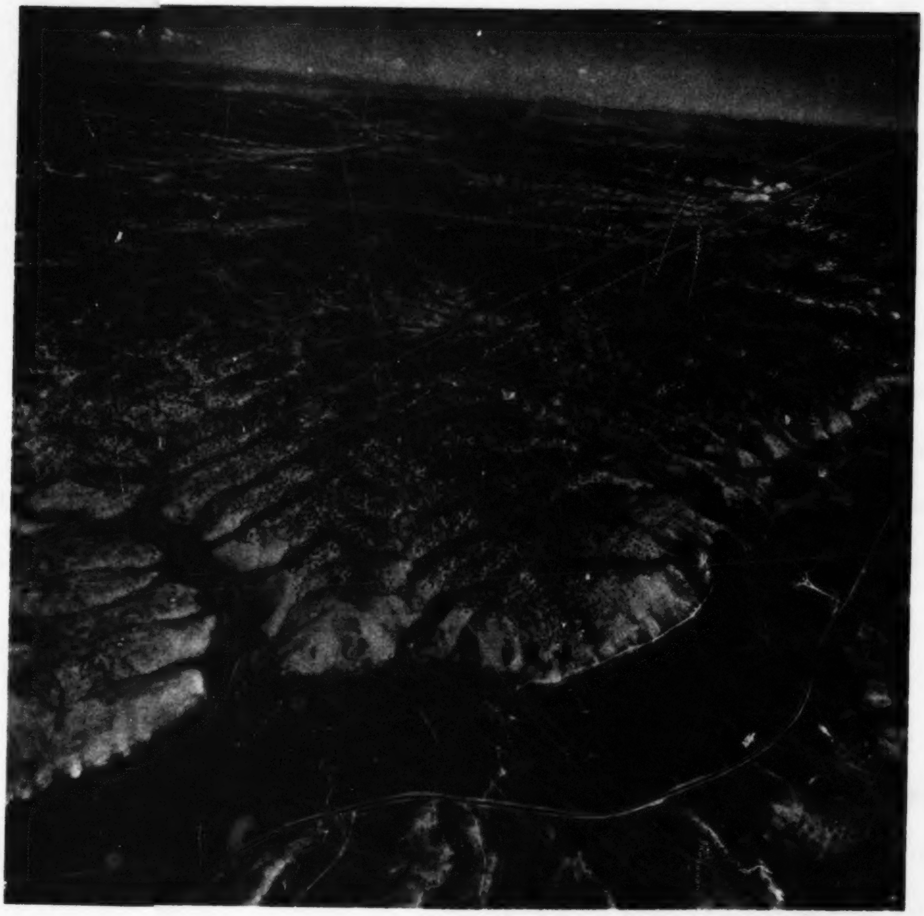
These streams have deeply dissected the Roan Plateau, forming ranges with verticle escarpments at the top and steep, V-shaped talus slopes at the bottom. Schum and Olson (1974:6) note a total relief of nearly 4,000 feet in the Roan Creek basin. The north-tending streams and valleys provide routes of easy access to the total Basin, while the south-flowing streams provide access in a limited way. Parts of the three northern sub-areas are shown in Figure 3.

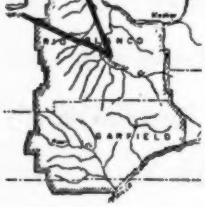
Climate

The climate of the Piceance Basin is transitional, between dry desert and a humid mountain regime. Consequently, climate range is from semi-arid to arid in the lower portions of the basin, with a different climatic sequence in the high portions of the Roan Plateau.

There are two main factors contributing to climate in the region. One is the prevailing westerlies and the other is the general oreographic uplift from west to east. Consequently, there is a parallel increase in precipitation from west to east (see Table 1).

There are two wet seasons--late summer and early fall, a period dominated by conventional thunder storms which are sporadic in nature--and a winter snowfall season dominated by regional storms (Jennings 1975).





(Area of Basin covered by oblique photo)

FIGURE 3

THE PICEANCE BASIN LOOKING NORTHWEST

(Piceance Creek in foreground with Square S Ranch to the right center. Photo courtesy Hardwick and Associates.)

TABLE 1

CLIMATIC SUMMARY OF THE PICEANCE BASIN, NORTHWESTERN COLORADO

TEMPERATURE

Station	Mean Jan. Temp.	Mean July Temp.	Max - Min
Meeker, Colorado	20.6°	64.6°	103° -43°
Rangeley, Colorado	17.5°	69.1°	106° -37°
Rifle, Colorado	23.0°	71.0°	104° -34°

KILLING FROST

Station	Last Killing Frost-Spring	First Killing Frost - Fall	Growing Season
Meeker, Colorado	June 15	Sept. 10	87 days
Rangely, Colorado	May 27	Sept. 15	111 days
Rifle, Colorado	May 12	Sept. 30	141 days

PRECIPITATION IN INCHES

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Meeker	.97	.86	1.31	1.59	1.44	.98	1.40	1.78	1.68	1.52	1.03	1.03	15.56
Rangely	.59	.86	.85	.58	.78	.60	.57	1.54	1.37	1.25	.64	.73	10.36
Rifle	.82	.60	.88	1.00	1.02	.40	1.17	1.07	1.19	1.13	.75	.87	10.90

Source: 1941 Yearbook of Agriculture "Climate and Man," U.S. Department of Agriculture

Precipitation

Precipitation in the basin ranges from 8.5 inches for elevations below 5,000 feet to an estimated 24 inches at elevations about 8,000 feet (Marlatt 1973:59), making a precipitation lapse rate of five inches per thousand feet. Greatest probability of thunder storms (thirty per cent) occurs in August; however, hailstorms are a rare occurrence (Marlatt 1973:59).

Snowfall occurs on an average of twenty days with annual totals on the plateau top exceeding 100 inches. Marlett (1973:59) reports evaporative demand as nearly three times precipitation rate in the valleys as compared to only 0.5 at high elevation. The high altitude soils' inability to hold moisture, coupled with summer evaporative demand, limits timber stands to north-facing gullies, along streams, and on protected hillsides (Marlatt 1973: 59).

Air Movement

Air movement within the basin takes two forms. Prevailing winds and the storm track are from the southwest and west-south-west (225 degrees to 247 degrees) at 9,000 feet throughout the year. Below 200-300 feet surface friction and shear will cause a reduction in velocity and a fifteen to twenty degree counterclockwise shift in direction. The other wind pattern, the mountain-valley wind feature (up-slope winds in daytime and a down-slope drainage at night), functions all year round (Marlatt 1973:60).

Wind Speed

Wind speed within the valleys and canyons is a function of canyon and valley width, with wind strength picking up in the lower, broader portions. Consequently, wide and open-mouthed canyons, and those portions of drainages where two valleys or canyons merge, will have appreciably longer, frost-free growing seasons due to cold air drainage than narrow and closed-mouth canyons.

Temperature

Temperature range in the basin is continental with hot summers and cold winters. Again, topography is the contributing factor with a cooling trend as you move to higher altitudes. Summer temperatures often range well over 100 degrees F., while winter temperatures can range below zero degrees F. for days on end (see Table 1).

Growing Season

Growing season varies from 87 days in Meeker to 111 days in Rangely and 141 days in Rifle (see Table 1). However, topography can have a marked effect on growing seasons. Wide, open-mouthed canyons will have appreciably longer seasons than narrow, closed-mouthed canyons due to cold air drainage.

Soils

Fox (1973) describes the soils of the Piceance Basin as being predominantly cool to cold, and calcareous or alkaline. The only real exception occurs in the pine zone where soils are more acidic (Jennings 1974).

Specific generic soil types identified by the Soil Conservation Service include: ustifluvent and fluvaquent associations; aridic arqiustoll and haploborall associations; eutroboralf and haploborall associations; and the higher altitude cryoborall and cryaboralf associations.

In general the soils are poorly adapted to agricultural use, although in the various low valleys timothy and alfalfa can be cropped.

Descriptions of the various soil associations are based on the U.S. Department of Agriculture's Handbook 436, "Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys," which was published in 1975.

Ustifluvents and Fluvaquents' Association

Ustifluvents are the fluvents that are found in the mesic, isomesic, or warm temperature regions. A few of the ustifluvents are frigid but not cryic. The ustifluvents are found in flood plains and low terraces bordering the flood plain in mid-latitude areas.

These deep, light colored, well-drained soils have a loamy texture and contain less than 35 per cent rock fragments. Depth to bedrock is over sixty inches. Typically, these soils are moderately alkaline and calcareous throughout. Flooding of these soils occurs usually during the rainy season. However, some flooding may occur in the summer caused by high-country snow melt.

Fluvaquents are deep, light colored, poorly drained soils. Like the ustifluvents, they too are moderately alkaline and calcareous and contain less than 35 per cent rock fragments. These are very young, water-laid deposits, characterized by either fine or coarse stratification that reflects deposition of sediments under changing currents and shifting channels.

Vegetation can be the result of irrigated cropland or, if growing season is too short, it may be used for rangeland or for wildlife. Typical, natural vegetation includes cottonwoods and willows adjacent to streams, and timothy, alfalfa, and various grasses.

In the Piceance Basin these soils are found in Piceance Creek, Yellow Creek, and Duck Creek.

Aridic Argiborolls and Haploborolls' Association

Aridic argiborolls and haploborolls occur in the uplands, fans, and on the valley-side slopes of the Duck Creek area of the Piceance Basin. Parent material is weathered shale or sandstone. The areas where these soils are found range in elevation from 6,000-9,000 feet, range in slope from two to fifty degrees, and have a soil temperature of 45 to 49 degrees F. Precipitation ranges from 15 to 25 inches annually, and the frost-free season is between 80 and 115 days.

Within this soil regime, aridic argiborolls occupy about sixty per cent of the regime and the aridic haploborolls twenty per cent. The remaining twenty per cent is made up of similar soils of less than twenty inches depth and rock outcrops. The surface layers are neutral, with alkalinity calcareousness increasing to moderate levels as depth increases. Depth to bedrock ranges from twenty to sixty inches.

The haploborolls are very similar to the argiborolls except that they have less well developed sub-soils.

Use of this association is generally restricted to rangeland and woodland grazing. Native vegetation is mostly grass and shrub but can include oakbrush and pinon pine. These soils are found in the area south of Duck Creek and north of Corral Gulch and east of Yellow Creek.

Eutroboralfs, Rock Outcrop, and Haploborolls' Association

Eutroboralfs are moderately deep to deep, light colored, well drained soils with clay-like texture. Rock fragment content increases with depth but typically comprises less than thirty per cent of the soil volume. These soils are usually found on steep mountain slopes and on slopes that range from thirty per cent to fifty per cent or more. Depth ranges from twenty to sixty inches with the tendency to become more calcareous as depth increases. Surface layers are typically acidic to neutral.

The haploborolls have already been described above.

Native vegetation associated with these soils within the Piceance Basin includes as the tree layer Gamble's oak and Douglas fir in open stands and dense clusters. Shrub cover includes juniper, serviceberry, mountain mahogany, and kinnikinick. The herbaceous layer includes wheat grass, fescues, needlegrass, mountain muhly and a variety of forbs and sedges.

This soil zone is in the process of developing into a mollisol similar to the argiborolls and haploborolls previously described. This soil association is found north of Duck Creek and both west and east of Yellow Creek in the upland regions delineated by the major drainages.

Typic Cryoborolls and Typic Cryoboralfs' Association

These soils are found in materials largely weathered in place from sandstone and shale. Elevation ranges from 7,000 to 9,000 feet within the study area, and slope ranges from fifteen to fifty per cent. Mean soil temperature ranges from 35-42 degrees F., and the frost free season ranges from 20 to 85 days. Depth to bedrock is usually over forty inches. Alkalinity ranges from neutral to moderate.

Typic cryoborolls usually contain from 35 to 85 per cent rock fragments and typically these soils are medium acid to neutral in the upper part to slightly acid to moderately alkaline in the lower part.

Native vegetation is quite variable with fir and aspen dominating the north facing slopes and oakbrush and sage with grass understory dominating other expanses.

In terms of antiquity the ustifluvent and fluvaquent soils in the valley bottoms are probably attributable to the Holocene period. The rest of the soils described have a reasonable antiquity as far as human use is concerned, being attributable to the late Pleistocene or early Holocene in date.

Water Resources

The large rivers, Green, Yampa, White, and the main stream of the Colorado receive most of their water from the higher elevations adjacent to and upstream from the Piceance Basin. The Basin does, however, contribute to the main rivers (see Table 2) (Coffin et al. 1971).

Normally, flow reaches a maximum during the snowmelt season with decline in flow starting around June or July and reaching low flow in either September or October. Low flow rates are sustained throughout the winter. Parachute and Yellow Creeks are often dry, or

TABLE 2

WATER PRODUCTION OF PICEANCE BASIN IN NORTHWESTERN COLORADO

LOCATION OF STREAM FLOW STATION	PERIOD OF RECORD	DRAINAGE AREA SQ. MILES	AVERAGE DISCHARGE CFS*	EXTREMES OF DISCHARGE CFS*	
				MAX	MIN
Parachute Creek at Grand Valley	4/1921 - 9/1927 10/1948 - 9/1954	200	30.3	738	0
Roan Creek near De Beque	4/1921 - 9/1926 10/1962 - 9/1967	111	40.3	1220	3.2
Piceance Creek at White River	10/1964 - 9/1966	629	17.00	550	.9
Yellow Creek near White River	10/1964 - 9/1966	258	1.37	1060	0

*CFS—Cubic Feet Per Second

(After Coffin et al. 1971)

almost dry, from December to April. Piceance Creek flow is more constant due to ground water discharge (Coffin et al. 1971).

Ground water in the Green River geological formation underlying the Basin is recharged around the margins of the Basin by direct infiltration of precipitation on the outcrops of aquifers and by downward percolation of water from narrow alluvial deposits in the higher stream valleys. The ground water moves down-dip toward the central portion of the Basin where it is discharged through springs and seeps in lower portions of the principal stream valleys.

Dissolved solids range from 250 to 25,000 mg/liters with water in the upper reaches of the main drainages containing less than 700 mg/liters of dissolved salts. Concentration increases as you move downstream. Principal ions are calcium, magnesium, and sodium bicarbonate (Coffin et al. 1971).

Vegetation

There are twelve vegetational zones within the Piceance Basin containing a total of 400 vascular plants. Of these 329 are native and 71 are introduced or exotic. One hundred and sixty-five (41 per cent) are reported edible by human beings (Yanovski 1936), and 258 (65 per cent) are consumed by mule deer (Kufeld, Wallmo, and Feddema, 1973) (see Table 3). There is considerable overlap in the plants consumed by humans and by mule deer. A complete listing of vascular plants found in the Basin is contained in Appendix A.

There is a small amount of duplication in these figures since some species are present in both the tree layer as trees and in the shrub layer as shrubs (a common occurrence with Gambel's oak, for example).

TABLE 3

DISTRIBUTION OF THE VASCULAR PLANTS IN THE PICEANCE BASIN OF NORTHWESTERN COLORADO

	Total No. Vascular Plants	Total No. Exotics	Total No. Human Edibles	Total No. Mule Deer Edibles
Tree Layer	14	4	40	10
Shrub Layer	49	1	28	38
Herbaceous Layer	337	66	127	210
TOTAL	400	71	165	258

The twelve zones are: the Riparian Woodland zone; Big Sagebrush Shrubland (Bottomland) zone; Greasewood Shrubland zone; Saltbush Shrubland zone; Hillside Fringed Sage and Grassland zone; Mountain Mahogany Shrubland zone; Upland Big Sagebrush Shrubland zone; Mixed Mountain Shrubland zone; Pinon/Juniper Woodland zone; High Elevation Grassland zone; Douglas Fir zone; and Aspen Woodland zone. Location of these zones is a function of climate, moisture, and elevation.

RIPARIAN WOODLAND ZONE

General Description (after Keammerer 1974)

This vegetation zone occurs in the flood plain of the Colorado River and on the alluvial terraces located only a few feet above the current level of the river. The Riparian Woodland zone is also found along the stream sides of Roan and Parachute Creeks.

The zone can be broken down into four sub-zones: Cottonwood forest, cottonwood-box elder gallery forest, mixed deciduous, and flood plain community.

Cottonwood Forest: these forests are found on the flood plain and low alluvial terraces of the Colorado River. In general the forests are quite open and the trees are sparsely distributed (22 trees per acre on the average). Broadleaf cottonwood is the dominant species.

The shrub layer within this sub-zone is made up primarily of rabbit brush, big sagebrush, and skunkbush. In many areas heavy grazing has destroyed the shrub layer. The herbaceous layer covers approximately 29 per cent of the area in the understory.

Cottonwood-Box Elder Gallery Forest: this sub-zone is found along the tributaries of the Colorado River located in the southern portion of the Roan Plateau (Parachute Creek and its tributaries, East Fork, West Fork, Middle Fork and East Middle Fork; Roan Creek and its tributaries Kimball, Carr, Brush, Clear and Conn Creek). This sub-zone is usually found as a narrow band (100-150 feet) along the streams. Narrowleaf Cottonwood and Box Elder are the dominant species.

The shrub layer is relatively sparse, averaging six per cent cover with the most common shrub being Western Virgin's Bower and wood's rose, with saplings of both the box elder and narrowleaf cottonwood supplying the greatest bulk of the shrub layer. This layer has been subjected to considerable impact due to grazing.

The herbaceous layer of this sub-zone has the greatest variety of species of all the communities in Parachute Creek. Cover ranges from fifteen per cent (heavily grazed) to 52 per cent in non-grazed stands with an overall average of 39 per cent.

Mixed Deciduous: occurs adjacent to the intermittent streams of the lateral gulches that drain into Parachute Creek. It consists of small, heterogeneous communities of narrow and broadleaf cottonwood and tree-sized Gambel's oak. Skunkbush and Wood's Rose are common.

Flood Plain Shrub Community: limited to recently formed islands and sand spits along the Colorado River. This is not a climax vegetation and in time will develop into cottonwood forest.

BIG SAGEBRUSH SHRUBLAND (BOTTOMLAND) ZONE

General Description (after Keammerer 1974, and Ward et al. 1972)

This vegetation occurs within the well-drained, broad, flat, valley bottoms and alluvial fans in both the Piceance Basin and the Parachute Creek Basin. In the Parachute Creek Basin this zone can also be found on the lower portion of the bordering talus slopes. Rabbit-brush, shad-scale and fringe sage are common shrub components. Indian rice grass and wheat-grass often occur. Normally soils associated with this zone are low in salinity but as salinity increases so does the incidence of greasewood until the zone merges into the greasewood zone. Shrubs range up to two meters in height.

In the Parachute Creek drainages, Keammerer (1974) reports a density of up to 3,700 plants per acre, but this quantity may vary for the Piceance Basin. The herbaceous layer includes Indian ricegrass and several varieties of wheat grass.

GREASEWOOD SHRUBLAND ZONE

General Description (after Keammerer 1974, Ward et al. 1972)

This zone is usually found in the broad, flat, valley bottoms with soils of high salinity and alkalinity. The water table is at or near the soil surface, sometimes for several weeks. Where salinity and alkalinity are low, rabbitbrush and big sagebrush tend to increase. Shrub height ranges from 1.5 to 2 meters. In the Parachute Creek drainage Keammerer (1974) reports a density of 1,245 plants per acre, but this may vary for the Piceance Basin.

The understory or herbaceous layer is poorly developed and in some areas is non-existent. When it does exist, it includes cheat and pepper grass, mustards, and fringe sage.

SALTBUSH SHRUBLAND ZONE

General Description (after Keammerer 1974, Ward et al. 1972)

This vegetation zone is found on steep and dry hillsides usually with a southern exposure. In the Piceance Basin it is often located on shale outcropping, while in the Parachute Creek drainage, it is located on the Wasatch foot slopes.

As the zone reaches into the upper portions of the Piceance Basin, it gives way to a mixed mountain shrub zone with mountain mahogany and the wax currant being the first species to appear. The herbaceous layer is sparse (four per cent average cover).

In the literature Ward et al. identify this zone as a shad-scale community (1972). The different terminology results from the differing names of *Atriplex canescens*. This paper will follow the usage outlined in Harrington (1964) and adhered to by Keammerer.

HILLSIDE FRINGED SAGE AND GRASSLAND ZONE

General Description (after Ward et al. 1972)

This community is found on very steep hillsides with sandy and unstable soils. Big sagebrush and rabbitbrush are important components, but the community is dominated by fringed sage and Indian ricegrass. Plant cover is usually less than twenty per cent and the shrubs are generally less than 0.5 meters high.

There is no analogous community in the southern portion of the study area.

MOUNTAIN MAHOGANY SHRUBLAND ZONE

General Description (after Keammerer 1974)

This community is found on steep (35 degree) north and northeast facing slopes below the Douglas Fir forest zone. Mountain mahogany is the dominant species (35 per cent cover, 3,586 individuals per acre), with juneberry occurring as a secondary dominant (fourteen per cent) cover, 2,551 individuals per acre). It is virtually impossible to traverse this zone on foot due to the density of the shrub cover which reaches eight feet in height.

The herbaceous layer is very sparse (two per cent) and low in species diversity.

There is no analogous community in the Piceance Basin proper. Traverses of Tracts C_a, C_b, Ryan Gulch, Yellow Creek, Piceance Creek, and Black Sulpher Creek, from the Piceance Creek to the Cathedral Bluffs, failed to locate this community north of the divide. It would seem to be a high altitude phenomenon within the study area.

UPLAND BIG SAGEBRUSH SHRUBLAND ZONE

General Description (after Ward et al. 1972; Ferchau 1973)

The obvious dominance of the big sagebrush is the main characteristic of this zone. It occupies more acreage than any other community within the Basin.

Based on altitudinal differences, Ward et al. have distinguished four different sub-communities within the larger community. They are: low elevation big sagebrush shrubland, mid-elevation big sagebrush shrubland, high elevation big sagebrush shrubland, and the big sagebrush of the cliffs and rocky breaks.

Low Elevation Big Sagebrush. This sub-community occurs below 6,500 feet (2,000 meters) and shrubs are rarely higher than 0.5 meters. Soils are sometimes slightly saline but rarely alkaline. Big sagebrush is always the dominant species but fourwinged saltbush can be found.

Mid-Elevation Big Sagebrush. This sub-community occurs between 6,500 and 7,500 feet (2,000-2,300 meters) and is located on rolling uplands. Soils are moderately deep and more water is available for plant growth because of higher elevation.

High Elevation Big Sagebrush. This sub-community occurs above 7,500 feet (2,285 meters). Big sagebrush attains heights of 0.7 to 1.0 meters and is usually accompanied by serviceberry, mountain mahogany, and snowberry. Soils are usually deeper than 0.5 meters. This community is analogous to Ferchau's (1973) plateau-top big sagebrush community which is found on ridge tops, gully bottoms, and hillsides.

Big Sagebrush Shrublands of Cliffs and Rocky Breaks. This sub-community occurs at mid-elevations where soil pockets can be found. It is similar to high elevation big sagebrush shrubland.

MIXED MOUNTAIN SHRUBLAND ZONE

General Description (after Ward et al. 1972, Keammerer 1974, and Ferchau 1973)

Tall shrubs (three meters or more in height) are dominant cover for this community which usually occurs between 7,000 and 8,000 feet (2,100-2,400 meters). The community is usually found in areas protected by topographic features such as gullies and northern exposures. Gambel's oak, serviceberry, chokecherry, snowberry, big sagebrush and mountain mahogany may become local dominants depending on moisture. The overall community can be divided into two general sub-communities: the oakbush shrubland and the serviceberry shrubland.

Oakbush Shrubland. Gambel's oak and associated species are not widespread within the Basin or on the Roan Plateau to the south. This sub-community tends to be restricted to gullies, depressions, and lower slope positions of the upper Piceance Creek and to the edges of valley bottoms and gullies along Roan and Parachute Creeks. Trees are small, fifteen to twenty feet tall and four to five inches in diameter. They occur in high densities (436 trees per acre).

The shrub layer is essentially Gambel's oak sprouts and saplings and can occur at densities of more than 8,000 plants per acre.

Serviceberry Shrubland. This again is a tall shrub community, but in this sub-community serviceberry is the dominant cover species with canopy of up to eighty per cent or more cover and plants up to ten feet tall. When mixed with oak, it is usually found on south, southeast, and southwest facing slopes. Herbaceous cover in both sub-communities is sparse (three per cent).

PINON-JUNIPER WOODLAND ZONE

General Description (after Ward et al. 1972, Keammerer 1974)

Pinon pine and Utah juniper occupy large acreages within the study area. Elevation range of the zone is 6,000-7,500 feet and is similar to the upland big sagebrush shrubland. Between the two zones they account for approximately seventy per cent of the vegetational cover in the Piceance Basin. Two sub-communities are recognizable, a low elevation pinon-juniper community and a high elevation pinon-juniper zone.

Low Elevation Pinon-Juniper Woodland. This community is located below 7,000 feet and is dominated by Utah juniper. Soils are usually dry and poorly developed. If the parent material is shale, Utah juniper will be the only tree present. On sandstone it will be joined by pinon pine. Big sagebrush is usually present in the understory.

High Elevation Pinon-Juniper Woodland. This community is located above 7,000 feet. Pinon pine becomes the dominant tree but Utah juniper is still present. Soils tend to be well developed and the shrub layer is dominated by big sagebrush. Rabbitbrush and mountain mahogany, chokecherry and serviceberry may be present.

The herbaceous layer in both zones is very sparse (two per cent) with junegrass, cheatgrass, Indian ricegrass and tansy mustard present.

The pinon-juniper woodland community is a mature, well-developed, climax community within the Piceance Basin. Studies of dated forest fires at Mesa Verde (Erdman 1970:1-26) would indicate that establishment of mature, climax communities of pinon-juniper takes at least 300 years.

HIGH ELEVATION GRASSLAND ZONE

General Description (after Ward et al. 1972, Keammerer 1974, and Ferchau 1973)

This community is found on windswept ridges at elevations of 8,000-9,000 feet. Dominant species include several varieties of native blue grass, Junegrass, and Idaho fescue in the north, while in the southern portion of the study area, Indian ricegrass is clearly the dominant species. In the southern portion of the basin wild rye is found in islands located in gully bottoms which may be due to localized variations in soil salinity.

Some shrubs (sagebrush, rabbitbrush, etc.) are found but have a distinctly stunted look.

DOUGLAS FIR ZONE

General Description (after Ward et al. 1972, Ferchau 1973, and Keammerer 1974)

This community occurs at high elevations (above 7,500 feet) and is usually restricted to steep (35 degree) north facing slopes. Douglas fir is dominant with the forests being classified as monospecific.

The shrub layer includes wax currant, snowberry, and mountain maple. Herbaceous cover is sparse (six per cent).

Many dead trees are present, killed by bark beatle. Because of inaccessibility and low productivity within the herbaceous layer, this community does not seem to be used by the local inhabitants.

ASPEN WOODLAND ZONE

General Description (after Ward et al. 1972, Ferchau 1973)

The aspen woodland occurs at high elevations (over 7,500 feet) and on north facing slopes. They tend to be more sheltered from solar radiation and wind than the areas with Douglas fir. Aspen forests have lush farb, grass, and shrub understory. Principal shrubs are oak, sagebrush, serviceberry, and snowberry. Herbaceous species include sedges and bluegrass.

Fauna

A total of 340 wildlife species are found within the Basin (Baker and McKean 1971, and Cringan 1973). Of the 340 species present, 83 are mammals, seven are classified as big game, four as small game, and nine as fur-bearers. The rest are classified as non-game by the Colorado Division of Wildlife.

Mule Deer

Since the turn of the century, the Piceance herd of mule deer has been famous for the quality of its trophy-caliber specimens and for the number of animals available for harvest. The Colorado Division of Wildlife presently estimates herd size at between 50,000 and 60,000 animals.

In general the bulk of the deer herd can be found at higher elevations in the summer and at lower elevations in the winter. Seven thousand five hundred feet seems to serve as the dividing line between summer and winter range. Movement to and from these respective ranges occurs as seasonal migrations in the spring and fall.

Warren (1910:23) notes:

> In autumn and early winter the deer move lower down; in western Colorado, in Rio Blanco and Routt

> counties, this is a regular migration, the animals coming from the higher, mountainous parts of those counties where most of them spend the summer and drifting gradually to the lower altitudes where there is little or no snow, gathering in herds, which twenty-five years ago and less numbered thousands of individuals.

The size of the animal itself in terms of potential meat yield and the size of the herd in sheer numbers makes the mule deer an ideal candidate for exploitation as a staple food item. Mule deer behavior, traits, movement patterns, and food preferences are expanded in the next chapter, Chapter III, The Mule Deer of the Piceance Basin as a Resource.

Elk

A small herd of elk also live within the Piceance Basin but the numbers are insignificant when compared with the mule deer herd. An annual harvest ratio of one elk to 256.84 mule deer is indicative of the disparity in numbers. The summer range-winter range migration pattern of the mule deer is also followed by the elk but in general elk tend to be found at higher elevations than mule deer.

Wild Horses

Wild horses are a potential resource within the Basin, but their presence there is a recent phenomenon. Herd size estimates range from 100 to 200 animals. Hartley Bloomfield, County Assessor for Rio Blanco

County, has noted a remarkable tendency for herd size to increase whenever local ranches are being assessed for taxes. Conversely, herd size tends to shrink with the departure of the assessor (Bloomfield 1975, personal communication).

Bison

In 1968 the Colorado Division of Game, Fish, and Parks established a small herd of bison on Upper Dry Fork of Piceance Creek (Baker and McKean 1971:17). Pressure from local ranchers caused their removal in either 1973 or 1974. According to Baker and McKean, no other bison are known to exist within the Basin. The reporting of a bison skull in Greasewood Gulch (sec. 1, Rg 97W, T1S) by W. T. McKean in 1964, argues for prior occupancy of the Basin by bison. If present, in all probability their numbers were small.

Bighorn Sheep

Although no bighorn sheep exist within the Basin today (numerous unconfirmed sightings of a small family group tend to refute this statement), there is evidence of their prior existence.

Numerous portrayals of bighorn sheep have been reported by Wenger (1956) in the rock art of Douglas Creek, which marks the western boundary of the Piceance Basin. In 1964 C. Reickart reported a bighorn skull in a cut-back on the Square S Ranch located on Piceance

Creek. The same ranch contains the only known rock art in the Piceance Creek Basin (Grady 1976) but no animals are portrayed on the existing panels.

Rabbits

Other mammals capable of providing meat in sufficient quantities to be attractive to man are the various varieties of rabbit found within the area. Warren (1910:35-36) reports astronomical numbers of rabbits being taken in drives in both Colorado and California. For example, a hunt conducted on December 22 and 23, 1894, near Lamar, Prowers County, Colorado, by 101 gunners yielded 5,144 rabbits in a day and a half. Warren also reports over 32,000 rabbits killed in organized drives in Prowers and Las Animas counties between 1893 and 1895. In the San Joaquin Valley in California 207 drives conducted between 1888 and 1894 harvested 494,634 rabbits.

Rabbit population growth rates tend to be cyclical in nature. Rabbits have high reproductive rates and as long as their food base is adequate, their population tends to grow rapidly. Even the concurrent growth of predators does little to check this growth rate. The main population check on rabbit numbers seems to be various varieties of density-dependent diseases that require large populations to achieve maximum contagion and viral effect.

Man can short-circuit the effect of disease by waiting until the rabbit population is large enough to be economically exploitable but not large enough to be disease prone.

Since no hunt or disease is ever totally effective, enough rabbits always survive to start the cycle again. Rabbits can, therefore, be repetatively cropped, provided a suitable interval is maintained for their population to recoup.

Other Species

Other species such as black bear, beaver, mountain lion, several varieties of water fowl, upland game birds, and a large variety of rodents make up the faunal inventory of the Piceance Basin. There are, of course, reptiles, fish, and insects as well, but human exploitation of the faunal resources seems to have been concentrated on the mammalian species and only a few of those. A complete listing of mammalian species is contained in Appendix C.

It is obvious that the Piceance Basin is ecologically diverse and rich in its potential food sources. A wide variety of plant foods are available and some can be remarkably productive at certain times of the year.

Animal resources are varied also and can be richly productive. Of all the animal resources present in the

Basin, the size, numbers, and potential meat yield of the Rocky Mountain Mule Deer clearly stands out.

Certainly, with resources to choose from as diverse and rich as those contained within the Piceance Basin, economic choice had to be an operative factor in site location.

Archaeology

Archaeological interest in the Basin is a recent phenomenon and is due primarily to the presence of astronomical amounts of oil-bearing shale making this area a prime target for energy development (see Fig. 1).

Several archaeological surveys (Kane 1973, Buckles 1974, Jennings 1974, 1975, and Olson 1975) have been conducted within the Piceance Basin and an attempt has been made using Jennings' surveys to develop a predictive model (Hurlbutt 1976).

Jennings' project (1974) was based on a sampling program of randomly selected sections (48 in number) which were extensively surveyed to recover remains of either scientific and/or historical interest. All work was done for the Thorne Ecological Institute's environmental impact statement.

Hurlbutt (1976) demonstrated that distance to water, elevation, and topographic variability were factors associated with site location and could be used to predict the location of sites in similar settings. But as Hurlbutt notes (1976:IV) his methodology is unsuitable as an explanatory tool.

In Olson's work surveys were conducted on blocks of land that have been identified as potential areas of oil shale development (C_a tract, access roads, wellhead sites, etc.). His purpose was to recover as much historical and archaeological material as possible and to establish which locations were suitable for more intensive work and which sites, if any, would be eligible for inclusion in the National Register of Historical Places.

Buckles, working at the confluence of the Piceance Creek and White River and the area to the south of the confluence, recovered a few sites and a portion of a point described as being characteristic of the "plainview type" (1974:29). On the basis of this find, he argues for a long antiquity of occupancy of the Basin.

Kane's survey (1973), conducted under a BLM contract within the Naval Oil Shale Reserve portion of the Basin, located 76 sites on the Roan Plateau portion of the Basin. With cancellation of the contract no further work (i.e., formulation of explanatory syntheses) was attempted. In general there are no architectural remains and the sites tend to be small in size. The accompanying artifact inventory of these sites also tends to be small and not overly complex (see Appendix G).

Of the 76 sites located by Kane, 26 sites (34.21 per cent) have points or fragments of points, while 50 sites (65.79 per cent) have manos, milling stones, and other implements associated with the grinding, crushing or pulverization of food. Sixteen sites (21.05 per cent) have both points, point fragments and grinding implements and 15 sites (19.74 per cent) are represented only by chipping debris. Eleven sites yielded cores and 6 sites produced scrapers. Only one potsherd was recovered on the plateau.

Based on site situation and on artifact content three categories of site function have been identified. The first, "campsite," has several variations and includes such descriptors as camp, campsite, temporary summer camp, summer base camp, large camp, and small summer camp. In several instances occupancy by one or more family groups is postulated. The second category includes sites identified as work areas or food processing areas or stations. The final category includes sites described as chipping stations. None of the above categories are mutually exclusive and several sites have multiple functional descriptors. For example, site 5GF 44 is identified as a temporary camp, housing one family and as a chipping station, while site 5GF 64 is identified as both a summer base camp and food processing area.

According to Kane (1973) "the entire area was apparently utilized by a prehistoric group of people as a summer home and foraging zone." Kane goes further and identifies this "prehistoric group of people" as being "Ute" since the area is known to be included in the homeland of the early Ute.

Olson's survey (1975) of the Duck Creek-Corral Gulch portion of the Yellow Creek Drainage for the Rio Blanco Oil Shale Project produced results similar to that of Kane. Sites tend to be small and the artifact inventory is not complex (see Appendix G). The main difference between the areas is the survival in a few sites of standing wickiups in the Duck Creek-Corral Gulch Area.

Of the 69 sites located in the Duck Creek-Corral Gulch area, 24 sites (34.78 per cent) have points or fragments of points while 26 sites (37.68 per cent) have grinding stones for the preparation of food. Twelve sites (17.91 per cent) have both points and grinding stones while 13 sites (19.40 per cent) are represented only by chipping debris. Thirty-two sites (47.76 per cent) have scrapers and 20 sites (29.85 per cent) have knives. Pottery was reported at four sites. Percentile comparison between the Naval Oil Shale Reserve and the Duck Creek-Corral Gulch is set forth in Table 4.

TABLE 4
PERCENTILE COMPARISON OF ARTIFACT INVENTORIES FOR THE TEST AREAS OF THE PICEANCE BASIN

Artifact	NOSR AREA (percentages)	Duck Creek-Corral Gulch (percentages)
Sites with points and point fragments	34.21%	35.82%
Sites with grinding stones	65.79%	34.33%
Sites with both points and grinding stones	21.05%	17.91%
Sites with chipping debris	19.74%	19.40%
Sites with cores	14.47%	0.0
Sites with scrapers	7.89%	47.76%
Sites with knives	0.0	29.85%

Major points of divergence occur in frequency of sites with grinding stones, scrapers, and knives. These divergencies will be discussed in chapter VII which discusses the ethnographic record.

Again the threefold classification of campsites, food processing areas, and chipping stations developed for sites on the Roan plateau seems valid for this area. The only modification is the inclusion of hide preparation activities with those of food processing areas.

In his summary Olson (1975:54-57) makes the following observations. He concurs with J. Jennings (1974) in the opinion that the area has been ecologically stable for the past 10,000 years. He notes that the single most abundant and dependable food resource on a seasonable basis in the Piceance Basin is the basin's Mule Deer herd and the presence of pinyon pine and various grasses which mature in late September and early October are also an exploitable resource within the basin and in particular in the Duck Creek-Corral Gulch area.

In conjunction with his appraisal of the vegetal resources, Olson reports that his survey turned up no evidence of agriculture within the basin, but based on the presence of potsherds and stylistically distinct points he argues for a Fremont occupation of the basin.

In areas adjacent to the Piceance Basin where Fremont occupation has been recovered it has marked the introduction of agriculture into northwest Colorado (Breternitz 1970). However, Fremont occupation of the basin does not inherently mean agriculture was practiced, rather with the short growing season of the basin it would seem the Fremont people exploited the basin for its seasonal resources rather than for its agricultural potential.

Olson reported that his assessment of the utilization of the basin underwent significant modification during the course of the survey and the subsequent analysis. His initial assumptions stressed the role of hunting, but subsequent study of the recovered tools and site locations indicated that the processing of vegetal materials was equally important. Based on the availability of resources in the Duck Creek-Corral Gulch area Olson, too, argues for seasonal occupancy of the area.

One site, 5RB 271, the Square "S" rockshelter, was excavated in August 1976 (Grady 1976); details of the excavation are contained in Appendix H. No diagnostic artifacts were recovered from this site, but the presence of "Fremont" rock art in the immediate area and the appearance of aboriginal field patterns adjacent to the site revealed on aerial photography would argue for occupation as early as the Fremont period.

In summary, the archaeology of the Piceance Basin is known primarily from either isolated surface finds or on the basis of surface surveys conducted since 1973. Artifact inventories by site tend to be small and usually consist of a few flakes as chips, perhaps a point or two, and possibly a few grinding stones. A few sites will produce an isolated potsherd. In one or two instances (Olson 1975) bone has been recovered. Perhaps the most unusual item in the archaeological inventory of the basin is the presence of standing wickiups.

All workers in the basin agree on the seasonal nature of the occupancy of the basin, but because of the nature of the known archaeological evidence, any attempt to reconstruct seasonal use will have to be based on evidence other than that currently available.

CHAPTER III

THE MULE DEER OF THE PICEANCE BASIN AS A RESOURCE

Many large animals (elk, deer, bison, bighorn sheep, and antelope) now live or have lived within the Piceance Basin. All are large enough to be considered attractive as potential prey, but in most cases their small numbers would preclude their use as staple food items. However, one specie, the Rocky Mountain Mule Deer (Odocoileus hemiones hemiones), does occur in large enough numbers to quality as a staple food resource.

Distribution

The distribution of mule deer is essentially restricted to western North America. Habitat preferences are broad within this large geographical area and ranging from lowland deserts and plains to high mountain areas. Of the eleven basic sub-species generally accepted, none has a greater range than the Rocky Mountain Mule Deer (Whitehead 1972:44 and Cowan 1965:339). Their general range is bounded in the north by the southern boundary of Alaska and Great Slave Lake, on the east by the southwestern shores of Lake Winnipeg, and on the west in California, Oregon, Washington State, and British Columbia where they are replaced by coastal varieties of Odocoileus hemiones. Northern Texas, New Mexico, and Arizona act as the southern boundary (Whitehead 1972:44).

Within Colorado the mule deer has a distribution ranging westward from the foothill zone located just west of Denver and extending to the Utah border (Warren 1910). In 1910 Warren noted the absence of mule deer in any plains' counties. Rodeck in 1972, however, noted mule deer present "far out into the Eastern Plains." Armstrong (1972) concurs with Rodeck's statement but notes that "on the Plains, mule deer tend to be localized and generally sedentary." The western two-thirds of the state has traditionally supplied 90 per cent of the deer harvest. Famous deer producing areas have always included Rio Blanco and Garfield Counties (Dalrymple 1973, Warren 1910).

Physical Description

Mule deer are rather blocky in appearance and lack the delicate appearance of the white tail deer. A good average buck stands about 40 inches (101.6 cm) at the shoulder and weighs around 200 pounds (90.72 kg), and an exceptional animal may hit 400 pounds (181 kg). Records from Modoc County, California, indicate hunter-dressed animals can weigh around 380 pounds (172.37 kg) with an estimated live weight of 475 pounds (215.46 kg). However, dressed weight in the field should average around 140-160 pounds (63.6 to 72.6 kg). In British Columbia, 65 adult does averaged 144 pounds (65.32 kg) dressed weight, while in Nevada 159 does averaged 77.7 pounds (35.24 kg) dressed weight, and 341 males in Nevada averaged 123 pounds (55.79 kg) dressed weight (Aldous 1948:5). Based on a study of 360 males taken in Modoc County, California, and arranged by antler class, average field dressed weights are shown in Table 5.

Coloration varies with the season. During the summer, the coat ranges from a pale, dull yellow to yellowish-brown. Sometimes it is distinctly reddish in color. The winter pelage ranges from a bluish-grey, or grey, to a warm brownish-grey color thickly peppered with black tips and rings on individual hairs (Whitehead 1972: 45).

A basic pattern of marking remains regardless of seasonal coat. There is a dark brown to blackish patch on the forehead which extends between and below the eyes on the face. Around the chin there is a black bar. The rest of the face, throat, and abdomen are white, as is the underside of the legs and the patch on the rump. There is a large expanse of white in the animal's ears which are rimmed in black. The tail is typically white and rounded with a black tip. Fawns are profusely spotted during the first year.

TABLE 5

AVERAGE FIELD DRESSED WEIGHTS OF THE ROCKY MOUNTAIN MULE DEER

Antler Class	Average Pounds Dressed Weight	Average Kilos Dressed Weight
1 & 2	104	47.17
2 & 2	118	53.52
2 & 3	136	61.69
3 & 3	147	66.68
3 & 4	166	75.30
4 & 4	178	80.74
4 & 5	189	85.73
5 & 5	201	91.17
5 & 6	200	90.72
6 & 6	177	80.29
7 Plus	249	112.95

(Einarsen 1965)

Mule Deer Senses

Mule deer have highly developed eyesight, sense of smell, and hearing. Since mule deer lack cones within the eye structure, they are color-blind. While bright colors do not seem to affect them, inappropriate shapes and movement do attract their attention. Shadows that move or are out of place can alert deer, and the sudden appearance of human hands and faces can induce panic.

Mule deer have capitalized on their highly developed sense of smell by adjusting their daily movements to make full use of this faculty. Days tend to find bucks high on hillsides where rising thermals bring scent of danger. In the evenings the deer move into the lower portions of the range to take advantage of the scent-bearing downdrafts.

Mule deer avoid running water and noisy situations that would tend to mask their hearing.

Breeding Patterns

Breeding season occurs in the fall with the cyclic occurrences set out in Table 6.

Einarsen reports that an average of 98 per cent of the does become pregnant (1965:371). Despite the variation and some abnormalities in the date of neck swelling, mating period, and the 210 day gestation period, the fawn drop consistently occurs in the period of lushest vegetation (Einarsen 1965:373). During the winter crisis

TABLE 6

BREEDING SCHEDULES OF THE ROCKY MOUNTAIN MULE DEER

LOCATION	DATE OF NECK SWELLING	MATING PERIOD	PERIOD OF ANTLER SHED	DATE OF FAWN DROP
Alberta Canada	10 October	15 Oct - 14 Nov	Feb - 15 Apr	7 - 14 June
Arizona	15 Nov - 31 Dec	15 Dec - 15 Jan	1 - 31 March	15 Jul - 15 Aug
California	1 Nov - 20 Nov	10 Dec - 27 Jan	8 Feb - 30 Mar	9 - 30 July
Colorado	1 November	15 Nov - 15 Jan	24 Dec - 20 Feb	15 Jun - 15 Jul
Nevada	20 October	15 Nov - 15 Dec	20 Jan - 15 Mar	10 Jun - 10 Jul
New Mexico	November	Nov - Jan	March	June - July
Oregon (Central)	20 October	9 - 30 Nov	28 Dec - 13 Mar	5 - 15 June
Utah	20 October	15 Nov - 15 Dec	20 Jan - 15 Mar	10 Jun - 10 Jul

(Einarsen 1965:373)

period, the development of the embryo is slow, but the pace of development picks up with the return of good forage (Einarsen 1965:375). Twinning is common and triplets are not unheard of. Activity of the doe following conception does not materially change, and the family grouping of yearling fawns and young bucks is quickly reestablished.

Personality

In general mule deer are gregarious animals and, in the Piceance Basin, it is not uncommon to see groups of 40 to 50 individuals. Groups of this size are usually made up of does and fawns, with a few "spikes" and "forkhorns" mixed in. As the males mature they leave the large female-dominated groups. Groups of bucks, ranging in size from three to six individuals, may hold together for several months, but will break up during the rut.

During the rut the males will fight but not as viciously as white tail deer. The fight is accompanied by bluff and light sparing but, when the animal is thoroughly aroused, he can be really vicious. The incidence of fighting to the death or of interlocking of antlers is much lwer among mule deer, however, than among white tail deer.

In a sense the mule deer's personality is rather like his build--big, bulky, solid. The mule deer is not a nervous animal. When forage is good and the mule deer are fat and contented, they remind you of domesticated animals. Even when being hunted, they rarely panic, rather they take off with stiff, four-legged bounds for a short distance, then stop and look back.

Behavioral differences based on sex of the mule deer are so marked that you almost have the feeling you are dealing with separate species. For example, does tend to move about during the day, graze or browse in the open and in the bottoms of valleys. Bucks are secretive, wary animals, who cling to cover. The hunter's typical complaint about bucks being "all shot out" does not stand up to census. In fact the sex ratios are fairly constant, 102-120 bucks per 100 does.

Bucks are more cautious than does. Even in the rut, in crossing a clearing does will cross first followed by a hesitant male. Bucks select different lie-up spots than does, and usually bed down shortly after daylight or at least by mid-morning. They prefer lie-up spots high and on the sides of ridges. This preference for height has three functional aspects. First, it prevents entrapment, since the deer has only to slip across the top of the ridge to get away. Secondly, height with its unobstructed view permits the buck to use its acute vision to identify and avoid potential threats. Finally, as noted earlier, the rising thermals of the daylight period carry scents from below. In contrast to the bucks does tend to lie-up in the open and can be found at almost any time of day bedded down in the grass or brush of creek bottoms.

Age is a factor in behavior that can be used to advantage by the hunter. The spike is a nervous, jumpy creature lacking experience and judgment. By the time the animal has reached the forkhorn stage, it has acquired some craftiness and is somewhat wary, but is still curious and has an adolescent lack of seriousness. In the rut it is preposterously wacky and easy to outwit. Past this stage, each season increases the male mule deer's wariness and knowledge.

Patterned Behavior

Daily behavior patterns tend to be repetitious but there are variations based on seasonal factors. In summer feeding starts just before daylight, 04:30-05:45, and lasts until 06:00-08:00 hours. The evening feeding period is from 16:00-18:00 hours until after sunset (Dorrance 1966:14).

Morning feeding is followed by bedding activity. Beds are usually located in thicker zones with a four to one preference for a zone fifty yards wide, starting at the edge of forest cover (Dorrance 1966:22-23). This is a classic use of the "fringe effect," the strategy involving proximity to food resources to minimize transport time.

Precipitation has little or no effect on the feeding deer. Dorrance reports (1966:75) that fog, mist, light rain, downpours, and even snowstorms do not effect feeding behavior.

Winter patterns are similar. Feeding commences just before daylight and lasts until 09:30-11:30 hours, when again the deer rest. The second feeding starts about 14:00-16:00 hours and lasts until after dark. There is, however, a greater tendency to feed all day (Dorrance 1966:56-57).

Environmental Preferences

Topography is an important factor in winter survival. Both Dorrance (1966:59) and Dalrymple (1973) report hill slope preference. Darrance notes that 54 per cent of the mule deer will be found on the upper one-third of the slope, 29.2 per cent on the middle one-third, and 16.3 per cent on the lower one third. Upper portions of the slope tend to be warmer than lower portions and the deer are much more difficult to approach from below. Greater use of south and west facing slopes are also noted by Dorrance (1966:59). These areas tend to be warmer and to offer preferred forage. Mule deer accept open grassland to a greater extent than do white tail deer. In the Rocky Mountain region their preference is for open forest.

Regardless of vegetation, a common feature in terrain preference of the mule deer is slope. Mule deer are at home on steep slopes up to 60 per cent, steep mountains, and rugged badlands. Dorrance (1966:84) records a coyote kill of a fawn on a slope with a gradient of 75 per cent. High rim rocks and crannies in high rock faces are favorite places for mule deer.

Temperature preferences in winter range between 15 degrees F. to 45 degrees F. (Dorrance 1966:59), but Dalrymple (1973) notes that the closer the temperature gets to freezing the harder it is for the deer to maintain weight. At near freezing temperatures the deer will lose weight regardless of how abundant or nutritious the food supply is.

Winter precipitation in the form of snow poses real problems for the mule deer. Sixteen inches in depth severely restricts movement; so much so that the deer "yard up," eat what's available, then starve. Two inches is enough to cut off grasses and sedges, since mule deer do not paw through snow for forage. Within the Piceance Basin there are areas referred to by wildlife specialists as critical winter range (Bob Hoover, personal communication). These areas are not necessarily rich in forage, rather they are areas that rarely develop excessive snow accumulations. Consequently they are crucial to the herd's survival in those winters--about one in every ten years--with excessive accumulations of snow.

Surprisingly, water does not seem to play a large role in mule deer location. The animal seems to be able to get by on fairly small amounts. However, it may compensate for its lack of drinking by eating prickly pear cactus, which is one-half water by weight. In hot weather there is, of course, greater urgency to drink, and a 200 pound buck (live weight), which usually consumes two to three quarts per day, can easily double that intake. If the source of water is near bedding and feeding grounds, the animal may drink fairly often. If, however, food and cover are abundant but water is not, mule deer will travel quite some distance to drink before they bed down for the day.

Cover is important in the life of the mule deer. It provides safety and comfort, it is a place to hide, and a place to cool off out of the sun. In Wyoming mule deer prefer to bed down on high shale ledges of buttes with the ledge and rock behind the deer providing cover. The deer will use the sunny side if cold or the shady side if warm. Eroded gullies with a few bushes are also used. Since deer suffer in intense cold, most animals move into dense cover to ward off the cold. Favorite places include dense clumps of conifers and deep snow beds. If cover is abundant, they will bed down under pinon or juniper. A common trait when being hunted is to dive into a dense thicket and freeze until the threat disappears.

Nutritional Requirements

While nutritional requirements fluctuate throughout the seasons, a close correspondence remains between quality and quantity of available browse and the maturation process. Growth in body size, weight, antler development, fawning, and nursing all occur in those periods when range plants are growing and are, therefore, most nutritious. Plant dormancy results in reduced growth rate of the deer, and activities other than those related to the food quest and raw survival are reduced to a minimum.

Even under optimal conditions, winter range can furnish only maintenance rations. If the dormancy of the winter range with its reduced nutritional values is matched by deep snow accumulations, mule deer expend more energy getting to food than the food can replace. Because of reduced nutritional value of browse, energy expenditure in moving through snow, and energy consumed in maintaining body heat, most mule deer lose 10 to 20 per cent of their autumn weight. Thirty per cent is the maximum loss they can sustain and still survive.

Winter survival is, therefore, dependent on the abundance and quality of the summer range, which must provide the necessary forage to build adequate reserves of fat to enable the animal to winter over. Failure to do this is fatal. The right combinations of severe conditions have resulted in winter kill of between 50 to 60 per cent of the total herd (Bob Hoover, Division of Wildlife, personal communication).

The animal's fat reserve is an indicator of the general, overall condition of the animal. White fat indicates an animal is in good condition, while yellow fat is indicative of poor condition. Both colors also reflect the quality of the animal's meat. White fat is indicative of an animal that is gaining weight; therefore, an animal with high quality meat. Yellow fat indicates weight loss and meat of poor eating quality (Dalrymple 1973). Antler condition is also directly dependent on how well the animal fed and how nutritious forage was when the antlers were forming.

Based on requirements of sheep and cattle, mule deer would seem to require for growth a feed with a crude protein content of 10 to 12 per cent; for maintenance, 7 to 8 per cent. Below 5 per cent, the animal will suffer from protein deficiency (Einarsen 1965).

Since mule deer concentrate their efforts on those plants that most efficiently fulfill their nutritional requirements, it is of no surprise that their winter diet shows a preponderance of shrub browse. Even when this preferred browse falls short of minimal crude protein requirements, it is still more productive of essential proteins. Hoover (personal communication) states that most winter kill seems to be based on protein deficiency (see Table 7).

TABLE 7

CRUDE PROTEIN CONTENT OF GRASSES
AND SHRUBS BY SEASON

	SPRING Before Blooming	SUMMER Blooming	FALL Seed	WINTER
Grass	15%-20%	7%-10%	5%-7%	2%-5%
Shrub	15%-20%	10%-16%	8%-11%	5%-8%

(Einarsen 1965)

Seasonal Food Use

As noted earlier, food, its quantity, and availability is the ultimate controller of population size. Larger populations of any species can be sustained if multiple resources can be integrated into an animal's food acquisition strategy. Considering the size of the mule deer herd in the Piceance Basin (some 50 to 60,000 individuals), specific exploitation of food in any one zone would result in its rapid exhaustion with a concomitant loss in deer population. This is precluded by the mule deer's annual migration cycle which permits it to exploit complementary resources on a seasonal basis, thus effectively integrating multiple resources into a viable strategy.

There are two ranges mule deer exploit, summer range and winter range (see Figs. 4 and 5). Depending on terrain, the 7,500 foot contour line or isohypses would seem to be the boundary between the two zones. Understanding of range and its characteristics is essential for successful deer cropping. It does little good to know that high country mule deer love to eat mountain mahogany (Cercocoyus montanus) if you are hunting winter range.

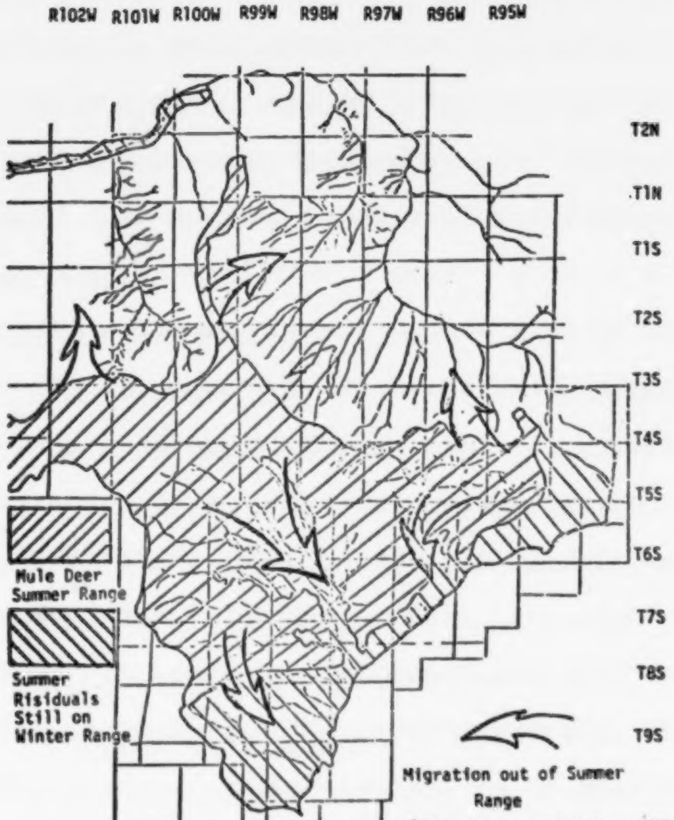
Certain observations dealing with migrations can be made. Distances between summer and winter range can be quite considerable, ranging up to 40 to 50 miles and, in a few cases, twice that amount.

Specific deer populations use the same winter range season after season, generation after generation (Dalrymple 1973). The same relationship with summer range probably exists as well but has not been studied in depth. Movement between ranges is a slow and casual process, but if a blizzard occurs when moving from summer to winter range, the pace of movement will pick up. If the terrain is gentle and open, migrations tend to spread out, actual migration routes tend to be ill defined, and concentration of deer will be low. In rugged terrain migration routes tend to be well defined and supportive of high concentrations of deer. Hunters who know these routes tend to have a high probability of success.

The Piceance Basin herd's summer range is in the Book/Roan Cliff area of Garfield County. This same range is also used by the Parachute/Roan Creek/Colorado River herd. During the summer members of both herds freely intermingle, but in the winter each returns to its respective area, and only on extremely rare occasions does a deer from the Piceance Basin herd winter in Parachute Creek, and vice versa. This preference for an area would seem to be learned behavior--the most intimately known area offers the greatest chance of survival.

Conversations with Bob Hoover, Division of Wildlife, confirm these observations. Moving animals into a new range area is a chancy proposition, not because the range is unsuitable, but because the animal is ignorant of the locations of those elements of the range needed for survival.

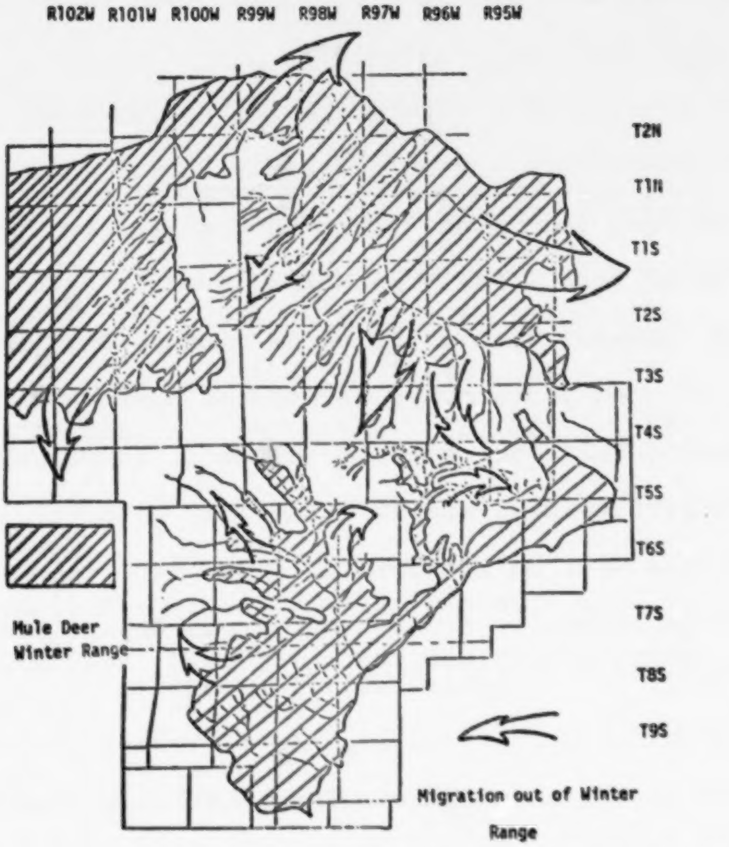
Intimately intertwined with summer and winter range are food preferences. On any given range there are a wide variety of foodstuffs (grasses, forbs, shrubs, trees) yet 75 per cent or more of mule deer diet is usually


R102W
R101W
R100W
R99W
R98W
R97W
R96W
R95W
T2N
T1N
T1S
T2S
T3S
T4S
T5S
T6S
T7S
T8S
T9S
▨ Mule Deer Summer Range
▧ Summer Risiduals Still on Winter Range
Migration out of Summer Range

(after Baker and McKean 1971, and McKean and Neil 1974a, b, & c.)

FIGURE 4

MULE DEER SUMMER RANGE, PICEANCE BASIN,
NORTHWEST COLORADO


R102W
R101W
R100W
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T3S
T4S
T5S
T6S
T7S
T8S
T9S
Mule Deer Winter Range
Migration out of Winter Range

(after Baker and McKean 1971, and McKean and Neil 1974a,b, & c.)

FIGURE 5

MULE DEER WINTER RANGE, PICEANCE BASIN, NORTHWEST COLORADO made up of less than ten species, and of these, three or four species will account for 75 per cent or more of the basic diet (Dalrymple 1973:149).

In general deer seem attracted to succulent, green food. Grasses are spring and early summer food, and when grass becomes too tough, there is a switch to forbs and other green food. Fall, with food production drastically reduced, demands a shift to woody plants (Dalrymple 1973: 146). In good years crops of unusual density can provide outstanding fall forage for mule deer. Acorns are a known fall favorite, and in especially good years juniper berries will be consumed in such quantities by mule deer as to literally stuff their stomachs (Dalrymple 1973:148).

February, March, and even April in cold years are crucial months, since snow cover inhibits movement, grasses and forbs are covered, and only shrubs can provide essential maintenance rations. Compositional studies of seasonal use of major forage groups in the Piceance Basin/White River herd are shown in Table 8.

Mule Deer Yield

Between 1955 and 1975 a yearly average of 4,763.13 deer were harvested in the Piceance Basin. Extremes range from a high of 11,958 in 1961 to a low of 2,001 in 1974, and are indicative of the effects of weather. The winters of 1972 and 1973 were particularly severe and

TABLE 8

SEASONAL USE OF MAJOR FORAGE GROUPS BY MULE DEER IN THE BOOK CLIFFS/WHITE RIVER DISTRICT OF NORTHWEST COLORADO

	WINTER		SPRING		SUMMER	FALL
	a	b	a	b	b	b
Trees/Shrubs	98%	97%	92%	79%	94%	97%
Forbs	2%	2%	4%	9%	6%	3%
Grasses, Sedges, Rushes	0%	1%	4%	12%	0%	0%

a. Book Cliffs District (Roan Plateau)

b. White River District (includes Yellow Creek, Piceance Creek and Little Hills)

Cited in Kufeld, Wallmo, and Feddema (1973) the magnitude of the winter kill loss is reflected in the 1973 and 1975 harvests (see Table 9).

With an annual average harvest of 4,763.13 deer and an average hunting pressure of 5,500.81 hunters per year, it is possible to calculate a yi ld rate per hunter of .87. Based on this and an average hunting season of 16.81 days, an average yield per day of 283.42 deer can be deduced. Obviously, this yield rate cannot be sustained for long periods of time, since the Piceance Basin portion of the White River herd numbers between 50,000 and 60,000 individuals. As it is, using an average herd size of 55,000 individuals and an average annual yield of 4,763.13 individuals, 8.66 per cent of the herd can be considered as the herd surplus. Dividing the average annual yield by 365 we find that the herd is capable of producing 13.05 mule deer per day or 91.62 deer per week.

Using 91.62 deer as a reasonable weekly harvest and based on dressed weights averaging 169 pounds for males (see Table 5), and allowing for a percentage of fawns and does, we can postulate an average yield of 5,955.30 pounds (2,701.32 kgs.) of meat per week, or 850.76 pounds (285.9 kgs.) per day.

Using the National Nutritional Council's 60 grams per day of protein as a minimal figure, 850.76 pounds (385.9 kgs.) of meat could support 6,431.72 people.

TABLE 9

MULE DEER TAKEN IN THE PICEANCE BASIN OF NORTHWEST COLORADO BETWEEN 1955-1975

YEAR	HUNTING* PRESSURE	BUCKS	DOES	FAWNS	TOTALS	LENGTH OF SEASON IN DAYS
1955	4093	1411	996	213	2620	16
1956	3601	1320	997	242	2559	16
1957	9165	5078	4881	1580	11539	33
1958	4072	1315	1276	388	2979	18
1959	4046	1535	1179	467	3181	17
1960	8319	5224	3769	1405	10398	20
1961	7653	4597	5444	1917	11958	18
1962	3848	1493	1066	275	2834	15
1963	7383	3974	4324	1419	9717	19
1964	4191	1259	1043	254	2556	19
1965	5773	1619	3719	869	6207	20
1966	4048	1033	1028	347	2408	16
1967	3563	1233	945	283	2461	19
1968	5720	2410	2350	752	5212	18
1969	5496	1887	1277	411	3575	19
1970	7132	3039	1558	140	4737	20
1971	5611	3046	Bucks only season		3046	13
1972	7743	3760	1625	117	5502	8
1973	4810	1681	571	94	2346	10
1974	4776	2001	Bucks only season		2001	10
1975	4474	2212	Bucks only season		2212	9

*Based on combined total resident and non-resident license sales and expressed in numbers of licenses.

Baker, B. D. and W. T. McKean 1971. Wildlife Management Unit 22 (Piceance) (for data through 1971)

and personal communication, Bob Hoover, Division of Wild Life (for data post 1971)

Using 135 grams (National Nutritional Council's recommendation for active people), the same amount of meat could support 2,858.54 people. These would have to be considered ceiling populations. Numerous ethnographic records attest to the ability of the American Indian to consume vast quantities of meat at a sitting. Joe Ben Wheat (1972) uses a figure of ten pounds per day in discussing bison utilization at the Olsen-Chubbuck site. Consumption of this magnitude would appreciably lower the carrying capacity of the Piceance Basin herd. Hunting techniques used by the Utes of northern Colorado are outlined in Chapter VII which discusses the ethnographic record of the Piceance Basin.

Other Animals Utilized

Rabbits were hunted by all Ute Indians but as an economic staple they were more important to Utah than Colorado Utes. In fact there would seem to be a negative correlation between mule deer consumption and rabbit consumption. Areas with large numbers of mule deer are characterized by low rabbit utilization and vice versa.

Communal rabbit drives were periodically undertaken by all Utes when rabbit population density was such that large scale community efforts would yield dramatic returns.

All Utes hunted mountain sheep, usually by drive to a waiting hunter. Bear were also taken, but because of their comparatively low numbers, they can be considered more of a delicacy than a staple item. After the introduction of the horse, bison were hunted by Ute Indians on the plains of Colorado, but bison were not, in all probability, a major resource of the Piceance Basin.

Beaver, ground squirrels, solves, coyotes, wild cats, skunks, prairie dogs, and porcupines were all hunted for either their hides or flesh, but again cannot be considered as staple resources (Smith 1974:57-59). Only the mule deer has the optimum size and exists in large enough numbers to qualify as a staple resource within the Piceance Basin.

CHAPTER IV

THE ENVIRONMENTAL MODEL

A basic premise of this study is that the principal goal of culture is the establishment of a viable, year-round food supply. As noted in Chapter I, study of this goal can be from either a subsistence point of view based on archaeological site content, or from a locational point of view, in which site location is viewed as an integrator of a multiplicity of food resources. Certainly the nature of the archaeological evidence presently available for the Piceance Basin precludes the former and supports the latter as a research method.

Problem Restatement

The problem then is to develop and test a model of site location that identifies those specific factors within the environment that impinge upon site location decisions. Second the model must be explanatory in that it explains why sites are where they are and finally the model must be integrative, in that sites found in diverse settings can be integrated into a cohesive whole. With a basic choice of plants, animals, or a mix of both as potential food sources in the Piceance Basin, and assuming use of these foods is based on rational choice, various facets of the principles of resource exploitation must be considered in the formulation of an environmental model.

The Environmental Model

The model from which a series of testable hypotheses will be chosen consists of several parts. The first two parts deal with some basic considerations inherent in plant and animal exploitation respectively, while part three considers population size as a factor in the exploitation of animals as a resource. Part four deals specifically with the mule deer of the Piceance Basin as a resource. Distance as a factor in the exploitation of resources, both plant and animal, is considered last.

Plants As a Source of Food

Plant foods have a rich bibliography in terms of studies of physiological characteristics and certain species (i.e., cultegens) have been studied in detail. In the studies on diverse aspects of plants and plants as food, certain basic facts stand out:

1. Precipitation, temperature, slope, soil conditions, and exposure seem to account for the location of most plants, plant associations, and the larger entities, the vegetational zones. As a consequence, plants that can be used as food are fairly evenly, but not randomly, distributed in space.

2. Because of differing characteristics in the physiographic makeup of plants, different portions of different plants are potentially useful as food.
3. Since all plants pass through a maturation process at varying rates, these edible portions become available at differing times. This is referred to as "seasonality" (Flannery 1968: 74-75).
4. As availability varies, so does quantity. Quantitative yield may vary from species to species, or it may fluctuate from year to year within a species; and finally, as all plants pass through the life cycle from immaturity to old age, their output will vary.
5. Human choice as to what plants to exploit and when to exploit them is an economic choice. This choice is referred to as scheduling (Flannery 1968:75-76). Choice can be based on rational criteria (mini-max strategy), or upon irrational criteria (the desire for condiments, etc.).
6. Since plants are stationery, any movement involved in their exploitation will be provided by the parasite species. As a consequence, men are required to (a) alter their behavior patterns to match the seasonal availability of

> plant food, or (b) bring selected plants into domestication and produce enough surplus to get them through the year with enough left over to provide seed. The former requires intimate knowledge of plants, where they are found, and when they are ready for harvesting. The latter approach requires a knowledge of soils, climatic conditions, and storage techniques.

The community concept of the plant ecologist is a basic principle in ecological thought (Odum 1959:246). It has varying definitions: "It includes all the populations occupying a given area" (Odum 1959:6); or "any assemblage of populations living in a prescribed area or physical habitat" (Odum 1959:245). The concept is important because it stresses that organisms involved usually live together in an orderly manner (Odum 1959: 246).

Consequently, man does not exploit plants, per se, rather he exploits the communities or portions of communities in which specific plants are found. Factors affecting community utilization include variety, density, and productivity.

Variety refers to the number of different species brought together to form a given community. Numerical expression is based on the number of different species in a given community.

Density, on the other hand, is the size of a given population in relation to a given unit of space. It is usually expressed numerically as the number of individuals, or population biomass, per unit of area or volume (Odum 1959:150).

Productivity is defined as the rate at which energy is stored by photosynthesis or chemosynthetic activity in the form of organic substances which can be used as food materials (Odum 1959:68). Odum (1959) further distinguishes between two kinds of productivity: gross productivity which is the total rate of photosynthesis and includes material consumed in the process, and primary productivity which refers to the rate of storage of organic matter in plant tissue in excess of respiration. It is measured in grams per square meter per day (grams/ M^2/day) (Odum 1959:68-74).

Vegetation communities that are characterized by high productivity tend to rank rather low in variety and vice versa. Density seems to be independent of either of the other two variables.

Part of the purpose of this study will be to determine which of these factors are operating and influencing site location within the Piceance Basin.

Animals As Sources of Food

While plants often make up the bulk of man's diet, they do not meet all of his nutritional needs. There are specific amino acids and proteins that only animals can provide.

Ethnographic and economic studies all seem to indicate a pervasive human preference for meat. Today, in fact, there is a positive correlation between a nation's Gross National Product and an increase in its meat consumption. On a worldwide basis there also seems to be an association of grain diets with poverty.

Animals, based on behavior, can be divided into two categories: solitary and social. While solitary animals are often taken, because of their low numbers, they cannot be considered a staple item, so virtually no economies are based on the systematic exploitation of solitary animals. Herd animals, on the other hand, usually occur in sufficient numbers as to make their exploitation economically practical.

In terms of economical exploitation we can recognize three basic exploitive patterns:

1. Emergency: normally animals exploited in emergency situations are few in number and fairly restricted in movement. Systematic exploitation would result in their extinction. Conservation, on the other hand, provides a ready reserve when all else fails and starvation is no longer just a possibility (an example is the musk-ox of the Arctic--see Wilkinson 1972.

2. Sporadic: these animals are worth taking but expenditure of effort is kept to a minimum. Examples would include an animal stumbled upon while performing some other task or the rabbit hunts of the Great Basin, where valleys were blocked and rabbits driven into lines of waiting hunters.
3. Staple: these animals occur in sufficient numbers and their rate of reproduction is such that they can be repeatedly and profitably exploited as a basic food resource without detrimental effects to the herd.

Animals too exploit plant food resources either directly as herbivores or indirectly as carnivores. The choices open to animals are similar to those of men. They tend to exploit plants that yield the maximum nutritional return for the least amount of expended effort. During periods of climatic stress it is possible to observe animals shifting from one resource to another, each in turn supplying less nutrition at greater cost.

Seasonality and scheduling are the crucial elements in man's successful exploitation of plant foods. However, acquisition becomes a different problem when the resource itself is mobile. Under these circumstances a new series of questions is raised. Where are the animals, when, and in what quantities? How and in what ways does man adjust his behavior patterns to coincide with the behavior patterns of the animals?

The answer seems to lie in the degree and character of the relationship or the degree and character of the overlap of social behavior patterns. Several terms are usually used to describe this relationship. They range from "dependence" to "symbiosis." In the diagram (Fig. 6), modified from Zeuner (1963) the nature of the symbiotic relationship can be based on who is exploiting whom. We can also see that there is little difference between seasonal cropping, continuous cropping, or parasitism. The differences that do exist are more of degree than kind.

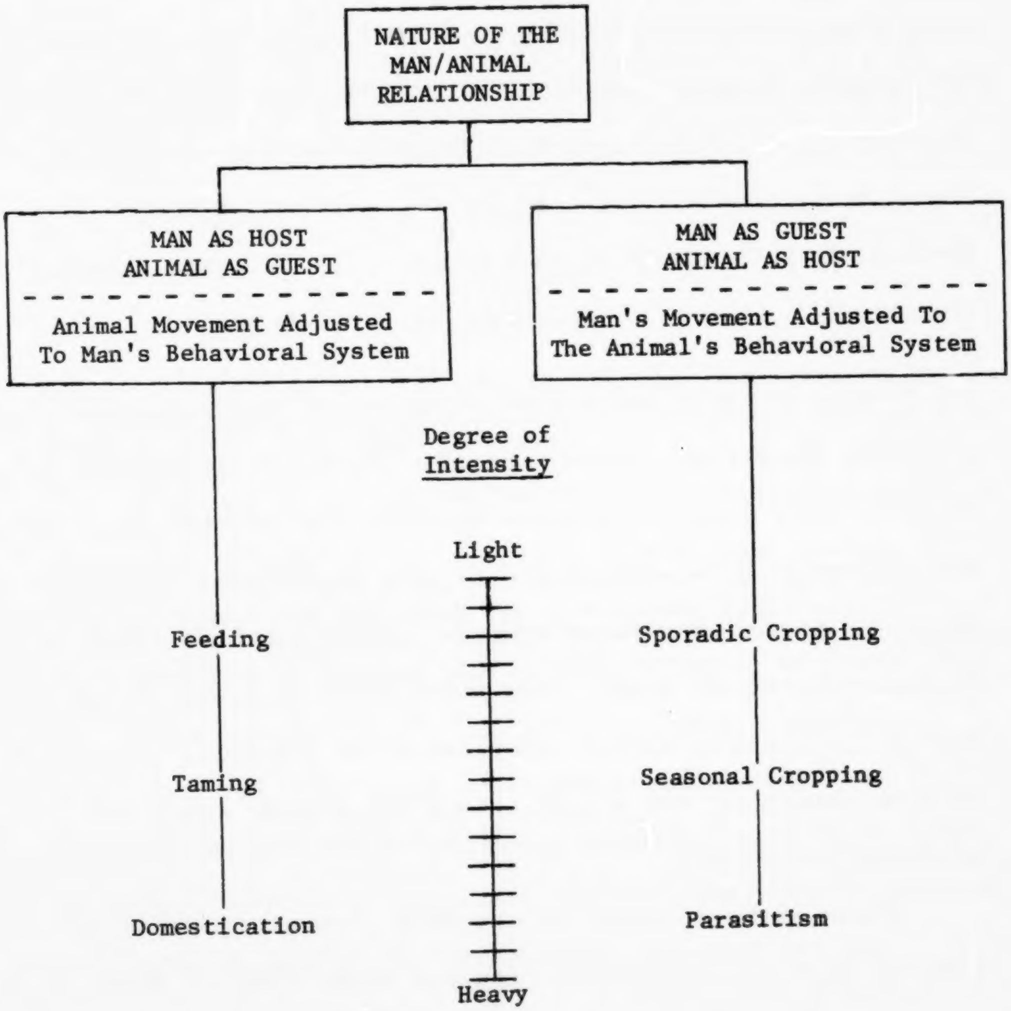
Seasonal exploitation or cropping is practiced by societies whose main economic activities lie elsewhere. Only at certain times of the year do they set out to exploit migratory herd animals. With the degree of human contact being intense for short periods of time, the archaeological deposit should produce a cross-section of the herd population or that portion of the herd being preyed upon, i.e., nursery herds (drives or jumps are indiscriminate in their slaughter).

Annual or continuous cropping involves societal movement that is parallel to herd movement, consequently herd location determines societal location. Degree of dependence is fairly high on an annual basis, but availability of other foods may assume a high degree of

FIGURE 6

NATURE OF THE MAN/ANIMAL RELATIONSHIP

IN TERMS OF OVERLAPPING BEHAVIORAL SYSTEMS


NATURE OF THE MAN/ANIMAL RELATIONSHIP
MAN AS HOST
ANIMAL AS GUEST
Animal Movement Adjusted To Man's Behavioral System
MAN AS GUEST
ANIMAL AS HOST
Man's Movement Adjusted To The Animal's Behavioral System
Degree of Intensity
Light
Heavy
Feeding
Taming
Domestication
Sporadic Cropping
Seasonal Cropping
Parasitism

(after Zeuner 1963)

importance for short periods of time. Since the maintenance of herd integrity is vital in this strategy, human contact with the herd is kept to a minimum. The archaeological deposit should be repetitive, i.e., large young or nearly mature males, etc.

Parasitism is a more intense version of continuous cropping. Societal movement is still parallel to herd movement. However, dependence on the part of human society is virtually total. There is a high degree of human contact with the herd, i.e., riding, milking, etc. Herd as host species is responsible for its own genetic makeup with only minimal human interference.

Population Size as an Economic Factor of Exploitation

The fact that larger animals are more economical to exploit than smaller animals is only one prerequisite to establishing an economically viable man/animal relationship. A second and more crucial requirement is that of animal population size. The population must be large enough to sustain either continuous or sporadic predation without damaging the species; anything else would be counterproductive.

Since most animals do not have runaway population growth, certain systematic factors must tend to keep populations fairly constant. Three factors or combinations thereof stand out in the literature as the principal growth limiting factors. They are predation, disease, and starvation.

Predation has a continuing day-to-day effect and tends to maintain environmental balances, but it does not result in catastrophic losses or in dramatic population reduction. Predation can be either random or selective in scope. In the former prey is taken regardless of age, class, or sex, while nonrandom or selective predation usually targets some specific portion of the prey population. This selection can be either conscious or unconscious. Selective predation tends to function on those members of the prey population that can be classed as surplus. Certainly, young, immature males tend to fall into this category.

Disease is an indiscriminate and irregular regulator of animal populations. It cuts across age, class, and sex grouping and can also attack those species that because of size escape the normal effects of predation.

Some varieties of disease are density dependent in that they require large contiguous populations to spread and to maximize their effect. Repetative attacks over extended periods of time may induce selective pressures to confer a degree of immunity on the species as a long-term, evolutionary effect. However, the short-term effect will be to reduce the species' population.

Starvation as a growth-limiting factor is also random in its effect. It usually occurs when the environment is incapable of sustaining the total population. It can be either externally or internally induced. External factors act independently of the species and include such things as natural disasters (i.e., severe winters, drought, etc.) and factors caused by human beings. Internal factors are those factors created by the species itself, and are usually density dependent (i.e., excessive population growth over and above environmental carrying capacity).

Starvation occurs in varying degrees. A state of malnutrition, for example, may provide enough food to keep adult animals alive but not provide enough nutrients for nursing females to sustain their offspring. Consequently, the young will die off. In a sense they are surplus because, with the return of favorable conditions in the next feeding season, they can be replaced. Under these conditions starvation can be selective in nature. Starvation is, of course, the final population limiting factor. If the others, predation and disease, are only nominally effective and population continues to grow, sooner or later a point will be reached when resources are so stressed that starvation is the only solution.

Within a natural population these three factors tend to maintain population levels of any species at an optimum level. However, fluctuations in weather conditions, both long and short-term in nature, can alter these optimal levels.

Wynne-Edwards (1962 and 1964) rejects the role of predation, disease, and starvation as regulators of population size. He notes that many animals have no effective predators or diseases and yet their numbers remain remarkably constant. He agrees that population size depends directly on the size of the food supply but also that normally all the individuals in the habitat get enough food to survive and, except for accidents, starvation is rare.

Animals do not, according to Wynne-Edwards, permit their population growth to get out of hand. Rather, they incorporate into their life cycle mechanisms that tend to limit population growth. It is also of interest to see that population limitations are maintained at levels appreciably below that of total or overexploitation of resources.

Mechanisms to regulate population are of two varieties--behavioral and homeostatic. Behavioral mechanisms include competition for territory or nesting sites. Here space is allocated only to certain members of the species. Territory usually carries with it the privilege of breeding, and the territory in question provides an adequate food base. Those individuals who are denied territory may die because of a lack of food base, but more often they survive and act as a breeding reserve. If the surplus members are driven out of the group, they lose security provided by the group and become easier prey, or they may be lost due to starvation induced by unfamiliar range.

Homeostatic mechanisms are activated when a stress point between population and resources is reached and they can take several forms. Stress may cause a reduction in hormone production and, consequently, a reduction in ovulation resulting in a reduced population recruitment rate. Stress can also increase the abortion rate with similar results. An interesting variation on this theme is reabsorption. In this process stress causes the pregnant female to reabsorb the embryo she is carrying. It is a common population regulation device of rabbits, foxes, and deer (Wynne-Edwards 1964).

Large animals can and do occur in large numbers. There are many species that have numbers bordering on the astronomical but because of their small size they have not become staples in man's diet. At best they occupy only a seasonal slot in man's total dietary quest. Herbivorous herd animals, on the other hand, seem to have the ideal combination of size and numbers to support annual or continuous cropping. It is with these species that man has traditionally formed close associations for the simple reason that larger herd animals are more economical to exploit than any other species.

Mule Deer of the Piceance Basin as a Resource

The rational behind the choice of mule deer as a resource is a simple one. It assumes that because of its size (50,000-60,000 animals) the Rocky Mountain Mule Deer herd in the Piceance Basin is the most profitable resource for man to exploit. Therefore, sites will be located to maximize access to the mule deer herds and to minimize cost in terms of effort expended in gaining access to these herds. Since the mule deer represent a moving resource, it follows that people who exploit them will practice a mobile economy.

Mobility of the mule deer on a seasonal basis follows a fairly simple pattern. In the summer mule deer move to higher elevations and in the winter they move to lower elevations. While many factors such as temperature preference, snow depth, browsing and resting behavior can account for daily behavior and movement of the deer, seasonal movement is dictated solely by nutritional necessity.

Of the four seasons only three--spring, summer, and fall--can provide adequate nutrition to enable the deer to successfully survive and grow. Winter is only capable of supplying poor maintenance rations. If a winter is particularly severe the result will be large-scale starvation and death. As a result, the mule deer must make the most of spring, summer, and fall forage to store large enough quantities of fat to enable them to survive the winter. This can best be accomplished by exploiting those areas of vegetation that offer the greatest return in crude protein on a seasonal basis. Acquisition of maximum food return can be accomplished in the following manner.

In the spring lowland streamside and marshland communities provide the first green food available in the growth year. Large quantities of starches are available in the root systems of the various cattails and rushes found in the wet areas, and streamside shrubs provide the earliest available new browse for the mule deer. Highland areas in the spring are still snowbound and no food is available.

In the summer lowland areas have finished their first burst of growth and the initial flush of young, tender, and highly palatable foods have passed their peak. Growth tends to slow down, and what growth does occur is being channeled into reproduction and seed production.

On the other hand summer in the higher elevations is a very productive period. Because of the short growing season, the maturation process is short and intense. As a result, comparatively large quantities of crude protein are available in a relatively small area. This combination of high quantity of resource in a rather restricted area makes the high country the optimal area to exploit in the summer. Resources located here provide the best opportunities for the deer to build up their fat reserves since energy expended in food acquisition can be kept to a minimum.

Fall in the high country disrupts this ideal balance between food availability and energy expenditure. The first frost terminates growth and productivity, and snowfall and cold increase energy consumption in exploiting decreasing resources. Conditions in the lowlands in the fall are entirely different. The dormancy of the summer is over and the grasses, shrubs, and tree communities are all coming into fruition. It is the last bountiful crop before winter sets in.

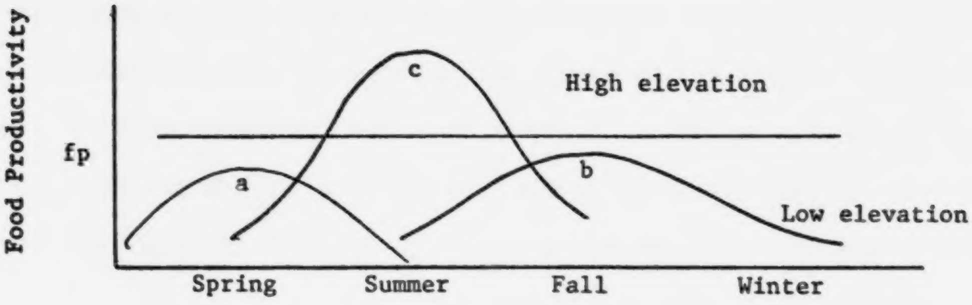
Winter in both the high country and the lowland areas is a time of hardship for both man and animals. The high country is completely snowed in and is for all practical purposes inaccessible. The lowland areas can provide some maintenance rations, but survival is ultimately dependent on fat stored during the summer season. Comparative freedom from snow accumulation in the lowlands permits the animals to move and exploit the maintenance rations available with minimal energy expenditure.

Seasonal availability can be diagrammed in the following manner (see Fig. 7).

The same basic exploitation pattern can be applied to human populations with streamside and marshland communities offering the first foods of the growth year.

FIGURE 7

LOCATION OF PRODUCTIVITY BY SEASON



a = Spring productivity
b = Fall productivity
c = Summer productivity

Summer is more profitably spent in the high country with movement into the lowland nut and berry producing areas taking place in the fall and early winter. The most critical time in the seasonal cycle for human populations is the period between late winter and early spring when all the stored food reserves are exhausted and the new food crops of the spring are not yet available. The Ute Indians referred to this time of the year as the "strip of buckskin" time (Smith 1974:278). The term refers to the period of acute hunger when the empty leather food storage sacks were cut into strips and boiled into a soup to provide some nutrition.

The same basic patterns of exploitation of plant foods used by the mule deer can profitably be used by people, but people have the added advantage of being able to crop mule deer as well to meet their protein needs. Yet similar needs between the two species, mule deer and human, makes parallel exploitation of specific vegetational zones on a seasonal basis a viable economic strategy.

Distance as a Factor in Resource Exploitation

If any resource occupies an important position in man's dietary regime, it is reasonable to assume man will locate as close as possible to that resource. Proximity in this case would tend to maximize the return and minimize cost of procurement.

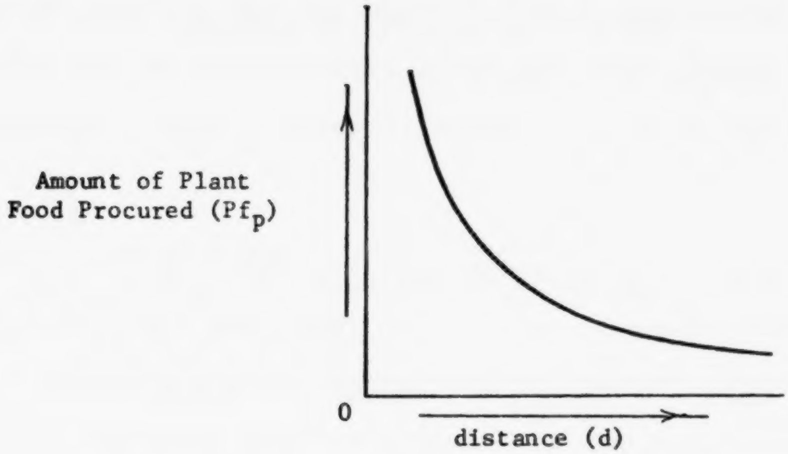
With static resources such as plants, this is an ideal strategy to employ. If we assume any site location's prime goal is the exploitation of plant resources, we can also assume that plant resources closest to the site are more heavily exploited than those farther away (see Fig. 8).

In other words, as distance (d) from the site increases, the amount of plant food procured (Pf_p) will decrease.

An entirely different situation exists if the exploited resource is animal. Introduction of man into an area results in the immediate evacuation of animals.

FIGURE 8

RELATIONSHIP OF PLANT PROCUREMENT TO DISTANCE



(Let 0 equal site location)

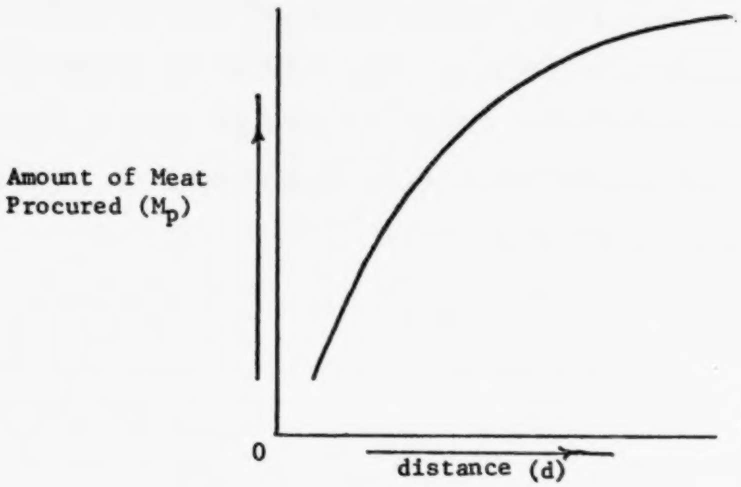
Consequently, for man to procure more meat he will have to venture farther afield, and the longer he is within an area, the greater will be the distance traveled (see Fig. 9) to procure meat.

In other words, as distance (d) increases from the site, the amount of meat procured (M_p) will tend to increase.

With both plants and animals to exploit, man has three options open to him. He can exploit only plant resources, only animal resources, or a combination of the two. Total exploitation of plants only or animals only would be optimizer strategies (Clarke 1968:94-95) and are considered high-risk procurement strategies.

FIGURE 9

RELATIONSHIP OF MEAT PROCUREMENT TO DISTANCE



(Let 0 equal site location)

A mixed blend of both animal and plant procurement could be classified as a satisficer strategy. Satisficer strategies studied in traditional farming methods produce 40 per cent to 70 per cent of the optimizer strategy (Haggett 1965:181), but as Clarke notes (1968: 95), satisficer strategies seem to be the preferred strategy in many different parts of society or societies.

Economic Consideration, Assumptions and Hypotheses

Since man is an animal, and like all animals has certain basic biological needs that must be fulfilled if he is to survive, and since man's primary adaptive tool is "culture," it logically follows that culture's basic goal is the establishment of a guaranteed, year-round food supply. Anything less would be suicidal. As a consequence of this overriding goal, a series of considerations may be drawn. These considerations are drawn in part from current thinking in the British school of economic archaeology. They certainly underlie the thinking of J. G. D. Clark (1973) and Eric S. Higgs (Higgs and Jarman 1969; Higgs and Jarman 1972; Vita Finzi and Higgs 1970).

1. In the long run man acts in a sensible, rational, economic manner. Deviations from this would tend to place a group or "culture" at an economically selective disadvantage.
2. Resources used by a group are defined by the characteristics of the natural environment, the technological capability possessed by the group, the group's economic perception, and the presence or absence of factors that produce resource stress.
3. Over the long term human groups will make use of those resources within their territory that are economical for them to exploit and that are within reach of available technology. (Territory in this context reflects this study's basic premise that the principal goal of culture is the establishment of a year-round

food supply and refers to the total area, region, or pattern of complementary resources required to fulfill this basic goal.)

4. Site location is, therefore, a product of economic choice. It is not a produce of "culture" or "social organization" or an unspecified attempt to "cope with environment." It is a conscious effort to exploit resources in the most rational manner possible.

Concomitant to the above economic considerations are a series of assumptions relating to the nature of the resources used by man.

1. In any given region resources are unequally distributed.
2. Resources used by a prehistoric group can be inferred with a reasonable degree of probability from archaeological (Hester 1964), ethnographical (Steward 1938), and modern environmental data (Higgs 1972, personal communication).
3. Resources have spatially definable distributions that can be inferred from present distributions and archaeological data.
4. Human beings can consume a wide variety of foodstuffs over a period of time. Out of this variety comparatively few foods will form a

major portion of the diet. These are classified as staple foods.

5. Only the staples occur in sufficient quantity to significantly affect the pattern of exploitation. In the case of a single resource, resource location determines site location. In the case of multiple resources, site location becomes a vector of forces or a saddle point of optimum choice to best exploit multi-resources. If the resources are dispersed, either in time or in space, seasonal migration can result.

With these assumptions and considerations a series of testable statements (hypotheses) may be made. As noted at the beginning of this chapter, this model should fulfill three functions:

1. It should identify those specific factors contained within the environment that impinge upon site location decisions.
2. Is explanatory in that it explains why archaeological sites are where they are, and
3. Is integrative in that sites found in diverse settings are integrated into a cohesive whole.

On the basis of the model developed above, certain general hypotheses may be drawn:

> Site location in the Piceance Basin is a function of and reflective of societal structure.

> Physiography exerts a major impact on site location in the Piceance Basin.
>
> The nature and distribution of vegetation is a major factor influencing site location in the Piceance Basin.
>
> The seasonal movements of the Piceance Basin's herd of mule deer exerted major influence on archaeological site location decisions.

Obviously most of these general hypotheses are inherently untestable, but with the formulation of more specific hypotheses dealing with selected factors implied by the general hypotheses, we can indirectly test these general hypotheses.

The first hypothesis, site location in the Piceance Basin, is a function of and is reflective of societal structure, is the only hypothesis that can be directly tested. Using point-pattern analysis we can determine if systematic forces are at work or if the distribution of sites represents a state of randomness.

The second hypothesis, physiography or geomorphology, exerts a major impact on site location in the Piceance Basin, must be reformulated into a series of testable hypotheses that deal with specific characteristics found within the basin. Testable factors include: distance to water, slope, aspect, and distribution of soils. Rationale for their selection is discussed in Chapter V, Methodology. The format chosen for the specific hypotheses is the conventional Null (H_O) and Alternate (H_A) format. The specific hypotheses are:

H_O 1: If the distance to water exerts no influence on archaeological site location decisions, then as distance to water increases there should be no significant change in archaeological site frequency.

H_A 1: If the distance to water exerts an influence on archaeological site location decisions, then as distance to water increases archaeological site frequency should decrease.

H_O 2: If slope is not a factor in influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of slopes present in the region.

H_A 2: If slope is a factor influencing archaeological site location decisions, then archaeological sites should be found within a clearly defined range of slope angles.

H_O 3: If aspect is not a factor influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of headings present in the region.

H_A 3: If aspect is a factor influencing archaeological site location decisions, then archaeological sites should exhibit a marked preference for certain headings and an avoidance of others.

H_O 4: If the distribution of soils exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the land-scope in a manner proportional to soil zone coverage.

H_A 4: If the distribution of soils exerts a marked influence upon archaeological site location decisions, then archaeological sites will be distributed non-randomly with regard to soil zone coverage.

The third hypothesis, that the nature and distribution of vegetation is a major factor in influencing site location in the Piceance Basin, is testable at both the general and specific levels.

H_O 5: If the distribution of vegetation exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the landscape in a manner proportional to the vegetational zone coverage.

H_A 5: If the distribution of vegetation exerts a marked effect upon site location, then archaeological sites will be distributed non-randomly with regard to vegetational zone coverage.

A second hypothesis dealing with vegetation will be tested at this point. It deals with the degree of parallel consumption by both man and mule deer of plants in the Piceance Basin.

H_O 6: If there is no significant similarity in the food preferences of man and the mule deer, then there should be little or no correlation between the foods consumed by both species.

H_A 6: If there is a significant similarity in the food preferences of man and the mule deer, then there should be a marked correlation between the foods consumed by both species.

This hypothesis and those that follow will also bear on the final hypothesis which deals with seasonal movements of the basin's mule deer herd.

If the distribution of vegetation does significantly effect the distribution of archaeological sites, it is imperative to determine first which characteristic of vegetation plays the dominant role. Characteristics include: variety, measured in numbers of species per square meter; density, measured in numbers of plants per square meter; and productivity, measured in grams per square meter per day.

H_O 7: If variety as defined above exerts no influence upon archaeological site location decisions, then an increase in variety will not produce an increase in archaeological site frequency.

H_A 7: If variety as defined above exerts an influence on archaeological site location decisions, then an increase in variety should result in an increase in archaeological site frequency.

H_O 8: If density as defined above exerts no influence on archaeological site location decisions, then an increase in density will not produce an increase in archaeological site frequency.

H_A 8: If density as previously defined exerts an influence on site location decisions, then an increase in density should result in an increase in site frequency.

H_O 9: If productivity as previously defined exerts no influence on site location decisions, then an increase in productivity will not produce an increase in site frequency.

H_A 9: If productivity as previously defined exerts an influence upon site location decisions, then an increase in productivity should result in an increase in site frequency.

Since mule deer are a mobile resource and tend to avoid man, the final hypothesis dealing with the seasonal movements of the basin's herd of mule deer and how these movements influence site location decisions, will be tested by site catchment analysis. This technique permits examination of vegetal distribution near or adjacent to the site.

H_O 10: If there is no significant difference between the observed percentages of vegetational zones contained within the catchment area and that of the regional universe, then the catchment will exhibit the same vegetational characteristics as the regional universe.

H_A 10: If there is significant difference between the observed percentage of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit different vegetational characteristics than that of the regional universe.

Rejection of the null hypotheses above and the sixth hypothesis dealing with man/mule deer food consumption will provide the basis for both a qualitative and quantitative estimate as to each site's resource exploitation strategy.

Test Implications

Rejection of the null hypothesis will be at the traditional .05 level.

The nature of the data base, the statistical tests to be used, and the problems involved in using modern environmental data are discussed in the next chapter, Chapter V, Methodology, while the actual testing of the hypotheses is contained in Chapter VI, Analysis.

CHAPTER V

METHODOLOGY

Part one of this chapter deals with the nature of the data base. It contains the the rationale for the selection of the basic variables chosen to test the specific hypotheses posed in the last chapter.

Utilization of modern environmental data requires some justification and arguments for the ecological stability of the Piceance Basin and are presented in this chapter.

The areas selected for study and the techniques used in mapping the distribution of vegetation within these areas are described in the sections devoted to sampling and specialized techniques used, respectively.

The nature of the statistical tests to be used to test the hypotheses formulated in the last chapter are described and each hypothesis and its appropriate test are formally presented in the last part of this chapter.

The Data Base

Data to support or reject this model is drawn from modern distributions of flora, fauna, and topographical features found within the Piceance Basin. The basic variables chosen for this study are water, soil types, vegetational cover, and topographic features.

There are two basic reasons for their choice. First, there is general agreement among both archaeologists and ethnologists as to their importance (Vayda 1969). Julian Steward, for example, in working with groups in the Great Basin noted three factors he found significant from the point of view of location. These were described as follows:

> Important features of the natural environment were topography, climate, distribution and nature of plant and animal communities, and, as the area is very arid, occurrence of water (1938:2).

He also noted that the basis of subsistence, population density, and the location and nature of cooperative enterprises were adjusted to these factors (1938:10). The SARG model prepared by Plog and Hill (1971) also stresses the effect that vegetation, landform, and drainage patterns have on site location. In this case, effect is measured by formulation of hypotheses that question whether or not human settlement patterns will vary as these specific factors change.

Second, each of the chosen variables, water, soil type, vegetational cover, and topographic features can be mapped, plotted, and measured on aerial photography (water: Zinke et al. 1960; soils: Frost et al. 1960; vegetation: Wilson et al. 1960, and Jay and Harris 1960; landform: Belcher et al. 1960; see also the 1968 UNESCO Toulouse Conference on "Aerial Surveys and Integrated Studies).

Ecological Stability in the Piceance Basin

The use of modern environmental data in explaining archaeological site distribution requires some justification and clarification if the proffered explanations are to have any validity.

Since no direct studies of environmental change have been conducted within the Piceance Basin, there is uncertainty as to whether or not presently observed conditions are representative of conditions in the past. It is possible, however, to make certain modest assumptions that may help clarify this problem. The first assumption is simple: present, observable, environmental conditions are the result of past conditions plus the processes of natural change and human modification. Second, since 1870, man has introduced new economic, exploitive techniques into the Basin that have undoubtedly had some impact upon the environment and account in part for the modern distributions of this data base.

The first problem, that of long-term change, could best be approached by examining studies of climatic change but since no studies are available for the Basin proper, we are forced to rely on studies peripheral to the area. These studies seem to indicate Holocene environments have changed little since the Pleistocene (Baerris and Bryson 1965; Bryson and Wendland 1967; Bryson, Baerreis and Wendland 1970; Heusser 1966; Matthews 1976).

Using fifteen degrees celsius as a base line, Matthews (1976:615) has established a graph (Fig. 10) based on mean annual air temperature. In the past 10,000 years only once in the period 6,000 B.P. to 8,000 B.P. does he indicate a mean annual air temperature change of more than one degree celsius. This is coincident with the altithermal period.

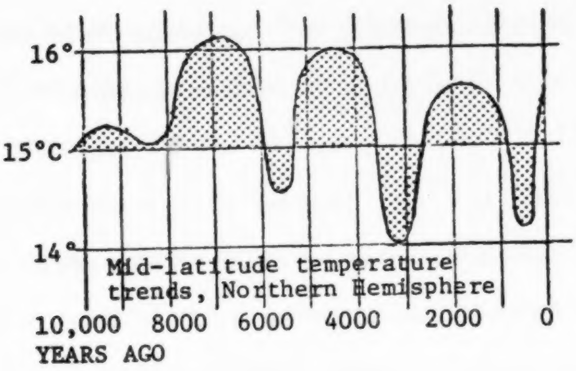
Matthews notes (1976:615) that a change of two degrees celsius in the mean annual air temperature could have profound effects on the environment. Higher temperatures could expand arable land and increase lushness of vegetational cover, but only if accompanied by increased precipitation. Alternatively, higher temperatures could result in increased aridity.

The problem of wetness or dryness has been discussed in the literature with Martin (1963:61) suggesting a shift in summer rain patterns in the southwest that produced a moist altithermal. This point of view is rejected by both Antevs (1955) and Benedict (1975).

By 5,500 B.P. (Matthews 1976:615), mean annual air temperature was below fifteen degrees celsius (14.6 degrees C) and this cooler period lasted till about 5,300 B.P. (see Fig. 10). Between 5,300 B.P. and 3,600 B.P. mean annual air temperatures approaching sixteen degrees celsius have been estimated. Another cool phase (mean annual air temperature of fourteen degrees celsius) follows. By 2,600 B.P. mean annual air temperature has

FIGURE 10

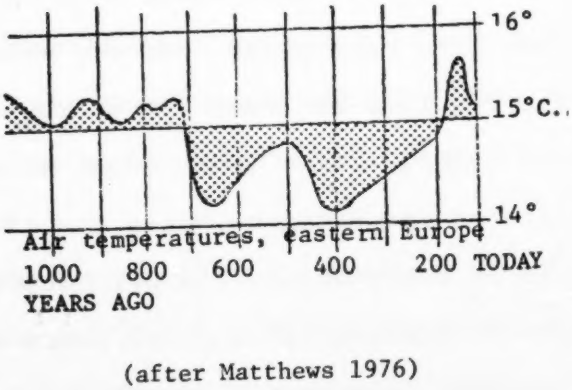
MEAN ANNUAL AIR TEMPERATURE CHANGES
PAST 10,000 YEARS



(after Matthews 1976)

FIGURE 11

MEAN ANNUAL AIR TEMPERATURE CHANGES
PAST 1000 YEARS



(after Matthews 1976)

risen to fifteen degrees celsius and this rise continued until a level of 15.6 degrees celsius was reached (around 1,600 B.P.). By 850 B.P. mean annual air temperature once again reached fifteen degrees celsius and temperature fluctuates generally on the warm side between 950 B.P. to 550 B.P. when the cycle entered the "little ice age."

The little ice age lasted with some variation into the present century. Since 1910 the general trend has been one of increasing warmth until a peak was reached just prior to 1940. Since 1940 there has been a general decrease (Matthews 1976:615).

Figure 11 showing mean annual air temperature for the past 1,000 years, indicates a peak cold period starting some 300 years ago when the mean annual air temperature dropped almost one full degree celsius. Even a change of this magnitude does not seem to have had a drastic effect on vegetation in western Colorado.

Studies conducted at Mesa Verde National Monument on dated forest fire burn areas indicate mature pinon/juniper forest requires at least 300 years to reach climax (Erdman 1970). There is no doubt that the pinon/juniper forests of the Piceance Basin are at climax and are comparable in every way to the Owl Canyon stand which has been dated at between 317 and 327 years old (Weber 1965:463). This would seem to indicate that even during the "little ice age" conditions were not so severe as to prohibit the seeding and germination of pinon and juniper forest in the Piceance Basin.

Of particular interest to this study is the record of the past 96 years. As noted in the graph (Fig. 12), mean annual air temperature has ranged from a low of 14.6 degrees celsius (about 1883) to a high of 15.7 degrees celsius, a range not exceeded in the past 3,100 to 3,200 years (Fig. 12).

Yet based on descriptions of the vegetation in the Piceance Basin contained in the initial land survey of 1883 (Moore 1883-1885), there does not seem to be any appreciable difference in either the vegetation noted or its distribution. Therefore, it seems reasonable to assume that the types and distributions of vegetation communities within the Piceance Basin have remained essentially unchanged for at least the past 3,000 years.

Weber (1965:464) even goes further describing the conspicuous flora of western Colorado (Astragalus, Atriplex, Cryptantha, Phacelia, and Gilia to name only a few) as elaborations of an old tertiary flora that radiated into the Great Basin out of a Mexican reservoir, thus arguing for a far greater antiquity than advocated in this paper.

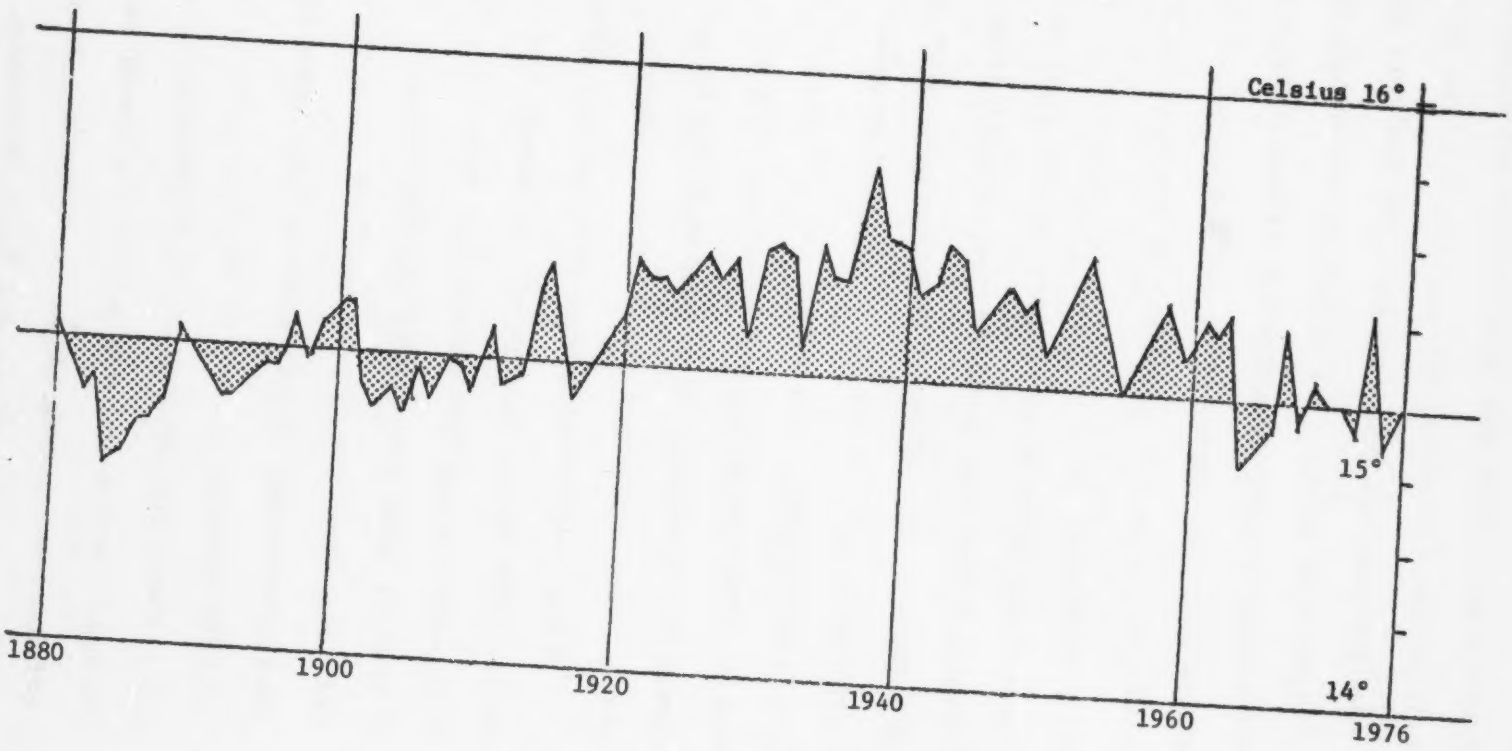
There are arguments as to whether or not introduction of cattle and sheep into the Basin has significantly affected mule deer range or numbers. Fortunately, a study by W. T. McKean and R. W. Bartmann, dated 1971 and

FIGURE 12

MEAN ANNUAL AIR TEMPERATURE CHANGES

PAST 100 YEARS

(After Matthews 1976)·



covering a study period from 1946 to 1971, deals with this question and indicates that sheep, cattle, and mule deer are non-competitive species and, consequently, introduction of sheep and cattle onto mule deer range should not have any detrimental effect upon the mule deer.

Sampling

The Piceance Creek structural basin encompasses some 1,600 square miles (1,024,000 acres). Since size of the area precluded total examination, a sampling strategy was selected and certain areas were chosen for detailed study. It was felt essential, however, to retain the total area as an intact region if reconstruction of an annual economic pattern of behavior was to be demonstrated. Areas selected for study in detail were the Duck Creek portion of the Yellow Creek drainage, the area between Duck Creek and Corral Gulch, a 9,000 foot wide strip running east-west between Yellow Creek and Piceance Creek, that portion of the Basin known as the C_a tract; and the Naval Oil Shale Reserve.

These particular areas were chosen for a variety of reasons:

1. They had been covered by prior archaeological surveys.
2. Quality aerial photography of these areas was available.
3. Topographic maps, soil maps, and hydrologic charts were available.

4. They represent a variety of altitudinal ranges and vegetational zones.
5. Detailed environmental studies (Ives, et al. 1974; Cook, et al. 1972; Thorne Ecological Institute 1973) covering these areas also existed.

Specialized Techniques Used to Study the Data Base

The need to study the distribution of the basic variables--water, soils, vegetation, and topography--over a very large area made aerial photography with its inherent ability to record infinite detail an obvious choice as a major source of synthesized data.

Aerial photography has long been used in archaeology to locate sites and to provide unique overviews of excavations. However, its use in providing useful information to the archaeologist is still in its infancy.

Correct use of aerial photography involves the establishment of a systematic approach to photo-interpretation. The general procedures used by most photo-interpreters have been set out by Kirk H. Stone in a series of articles (Stone 1948 and 1956) and are presented below in modified form:

A. Interpretation should be performed in a methodical way. Because of the palimpsest nature of the landscape--a mixture of both natural and cultural features--confusion can result without a well-thought-out methodical approach. To minimize any potential for confusion, eight steps are advocated as follows:

1. Research documentary, cartographic, and photographic sources to obtain materials on vegetation, surface features, drainage, soils, and climate. This step is similar to that taken by an archaeologist preparing to go into the field.
2. Determine the scale of the photography. This will depend upon the photographic source. Few archaeologists will have funds to permit flying to a given scale. In most cases photography flown for other purposes will have to be used, and complete data may or may not be available.
3. Plot and index photography so that the area covered by each vertical photograph and the number of the print will be plotted on a base map.
4. Make preliminary examination of photography. Photographs in each set (by scale) will be overlapped in the same manner in which taken and general patterns of surface features, vegetation, and drainage lines will be studied by naked eye and/or low-power magnifier or reading glass. Outline boundaries with grease crayon.
5. Compute appearance ratio. This is an estimation of the degree of exaggeration of slopes and heights of objects seen in stereo vision.

Computation is made by measuring apparent angle of slope with a template and comparing with actual slope derived from a survey of the area.

6. Make a preliminary stereoscopic study of photography. Vegetation clusters and regions with similar tone and/or texture are outlined during preliminary examination (see step 4) and will be tentatively identified from description reports on the area (see step 1) and from reconnaissance in the area. It is also possible to use analogous areas.
7. Perform subsequent field work and stereoscopic study in the field. Identifications previously made should be checked for accuracy. Variations in stereovision of tone, texture, stereo appearance, patterns and distributions are compared with appearances from the ground. Observations are made of the relationship of vegetation types to the physical properties of the land. This is referred to as establishing "ground truth."
8. Perform post field work stereoscopic study. Construct "P.I. keys," if needed, and make predictions.

B. Interpretation should be made from the general to the specific, and from small scale to large scale. The photographs should be viewed with the naked eye at the smallest scale available. A suggested ideal order would be satellite photography (ERTS), photo indices, mosaics, smaller scale verticals and obliques. This establishes broad regional patterns, and discontinuous patterns which need to be observed over large areas.

C. Interpretation must proceed from the known to the unknown. If the unknown item or subject is identified by map or report, no further work is needed. In any form of identification, certain questions must be asked--is it part of or directly related to the subject being studied. If the answer is yes, then the subject must be pursued. If not, the subject is dropped. Any tentative identification must also pose the question, what else could it be.

D. The photography should also be analyzed for its photographic qualities alone. Accidents can happen to photography, and spots, scratches, and development streaks can pose problems in interpretation. Natural effects like cloud cover and shadow can also pose some interesting problems.

Nature of the Aerial Photography Used

All photography used for this project was black and white vertical photography with 56 per cent to sixty per cent forward overlap. Where adjacent flight lines were used, forty per cent sidelap was the norm. All photography used existed in stereopairs. Oblique photography was not used since it does not readily lend itself to area mapping (see Fig. 13).

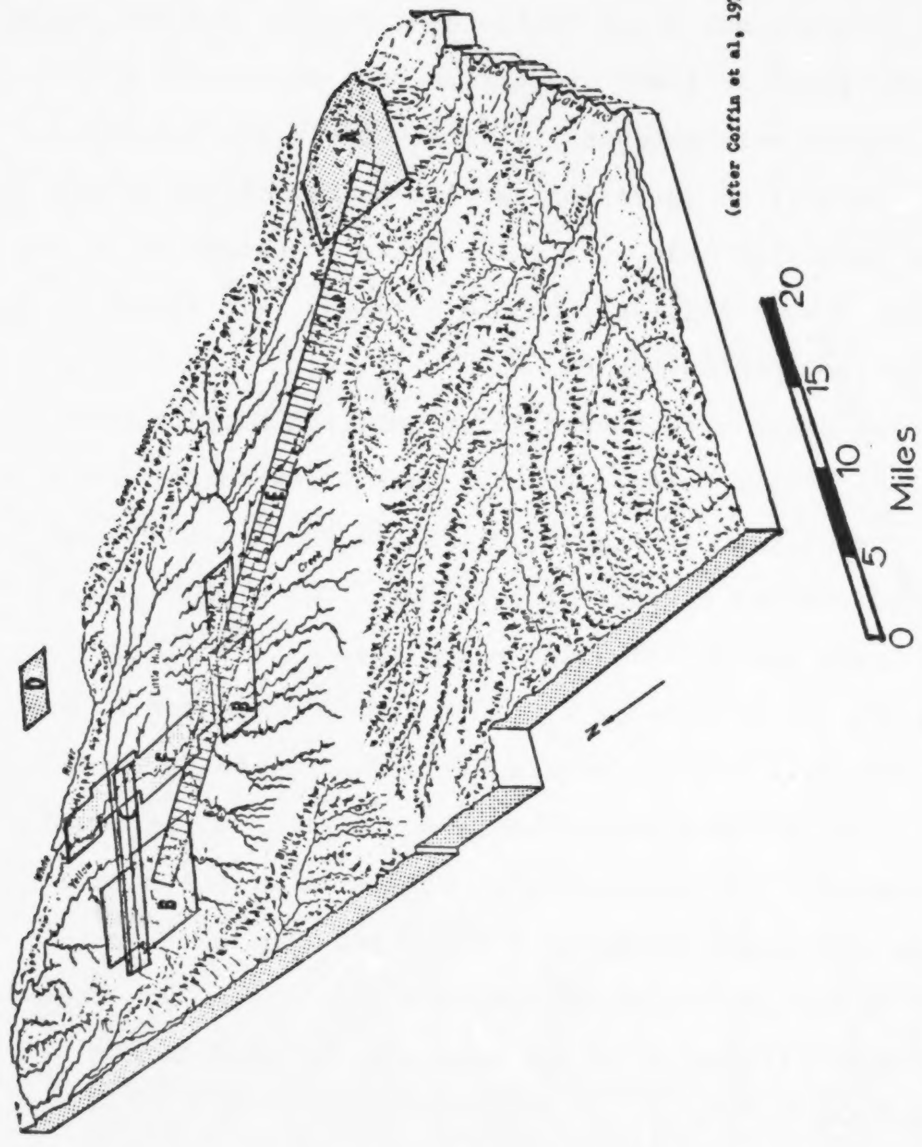
Sources of Photography

A variety of sources were used to obtain adequate coverage. Discarded Soil Conservation Service, U. S. Department of Agriculture, photography was utilized to map the Naval Oil Shale Reserve. Scale of this photography was 1/23,000 (see photo plot A).

U. S. Geological Survey photography of both C_a and C_b tracts dated 1948 was purchased and at a scale of 1/33,228 was adequate to cover not only C_a tract but Duck Creek as well (see photo plot B).

Through the generosity of Mr. Robert Hardwick of Hardwick and Associates an airplane and a Zeiss cartographic camera were made available to the investigator and additional coverage of one flight line at a scale of 1/12,000 was flown using Duck Creek as an axis. The flight started over the Little Hills area adjacent to the Square S Ranch and ended just west of the fork of Big Duck and Little Duck Creeks (see photo plot C).

Spot photo coverage of stereo-color pairs was also shot in the vicinity of the Square S Ranch. A three-shot strip was also made by the investigator and Robert Hardwick of a suspected Ute village site north of the White River (see photo plot D). A flight line some 37


A
B
C
D
E
F
White
River
Yellow
Little Hills
Creek
N
0
5
10
15
20
Miles

(after Coffin et al, 1971)

FIGURE 13

LOCATION OF PHOTO PLOTS A, B, C, D, E, F
IN THE PICEANCE BASIN, COLORADO

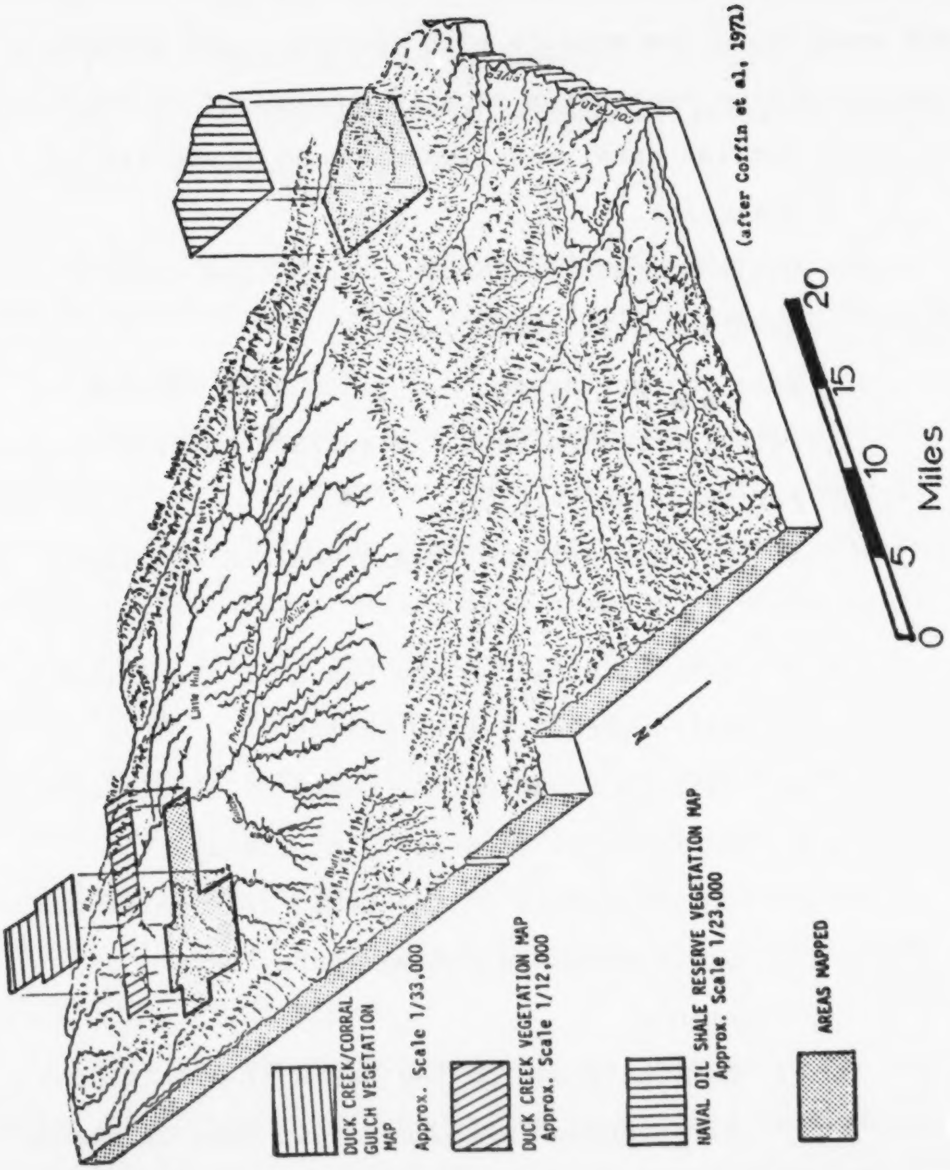
miles long and 9,000 feet wide was also flown from the East Fork of Parachute Creek to the 84 Ranch site on Yellow Creek to provide a link between the higher elevation vegetational zones of the Roan Plateau and the pinon/juniper zones at lower elevations (see photo plot E).

Format enlargements (18 inches by 18 inches) of obsolete soil conservation service photos of the Piceance Creek were also made available to the investigator by Mr. Hartley Bloomfield, Jr., County Assessor, Rio Blanco County (see photo plot F).

Two areas were chosen for vegetation mapping, the Naval Oil Shale Reserve and the Duck Creek/Corral Gulch area. Mapping of the Naval Oil Shale Reserve area was accomplished at a scale of 1/23,000. The area between Duck Creek and Corral Gulch was mapped at a scale of 1/33,228 and a separate and more detailed vegetation map was made from a 1/12,000 flight line supplied by Hardwick. It includes Duck Creek and the area to the immediate south. As noted earlier, it starts at the Little Hills area opposite Square S Ranch and continues westward to the confluence of Big Duck and Little Duck Creeks (see Fig. 14; copies of the maps are included in the appendix).

Vegetation Mapping

Kuchler (1967:85-98) outlines the advantages of using aerial photography in the preparation of vegetation


DUCK CREEK/CORRAL GULCH VEGETATION MAP
Approx. Scale 1/33,000
DUCK CREEK VEGETATION MAP
Approx. Scale 1/12,000
NAVAL OIL SHALE RESERVE VEGETATION MAP
Approx. Scale 1/23,000
AREAS MAPPED
N
0
5
10
15
20
Miles

(after Coffin et al, 1971)

FIGURE 14

LOCATION OF DUCK CREEK AND NAVAL OIL SHALE RESERVE VEGETATION MAPS WITHIN THE PICEANCE BASIN, COLORADO maps and the need for a well-thought-out mapping procedure and adequate ground control as well.

Mapping for this project was accomplished by preparing rough lay mosaics using nine inch by nine inch prints and overlaying the mosaics with acetate. The procedure used in making vegetation maps is summarized as follows:

1. Outline bare areas and areas with vegetation (natural).
2. Outline areas of forest, brush, and grass (exclude cultivated grass).
3. Note forest, brush, and grass distribution in relation to drainage and surface configuration.
4. For forests:
    a. Outline areas of evergreen and deciduous trees.
    b. Outline areas on the basis of significant differences in tree height.
    c. Outline areas on the basis of significant differences in density of stand.
    d. Outline areas on the basis of significant differences in photographic texture of stands.
    e. Outline areas on the basis of significant differences in photographic tone of stands.
    f. Outline areas on the basis of shape.
    g. Outline areas on the basis of repeating patterns or combinations of distributions,

height, photographic tone and texture, and shape of stand.

h. Outline areas of associations (pinon/juniper, etc.).

i. Outline areas of genera.

j. Determine general characteristics of undergrowth.

In those zones that are primarily brush and grass the procedures used within forest cover (items 4b through 4h) would be repeated.

Scale is crucial to detailed mapping of specific species within a community. The scales of the photography available to the investigator precluded identification of specific species within stands of shrub or in grasslands, but the stands themselves were readily identifiable. Photography at a scale of 1/12,000 did permit identification of specific pinon and juniper shrubs, individual stands of black sage (_Artemisia frigida_) within a grassland setting, and distinction between big sage (_Artemisia_ _tridentata_) and rabbitbrush (_Chrysothamnus_ _nauseous_).

Zones and vegetation communities delineated on the aerial photography were subjected to ground examination to establish the validity of the zone identification. Since the photography was shot at different times of the year, the same areas were revisited on a seasonal basis to note changes in the appearance of the vegetational zones. The aerial photography was taken into the field and direct comparison was made between the return on the photograph and the vegetational zone in question. Spot checks were also made when two or more zones exhibited identical photographic characteristics. Such checks inspire confidence in establishing analogous comparison; consequently, a zone with identical visual characteristics to a known zone is interpreted as being an identical zone.

Estimates as to food availability by zone were computed for variety, density, and productivity. Locations of known archaeological sites were plotted on the vegetation maps to permit the study of each site's environmental setting.

In addition to plotting site location a catchment area with a radius of 1,000 meters was also constructed around each site in an attempt to relate site location to portions of the environment that may have been exploited but lack evidence of human occupation. This meets the locational implications of plant exploitation as resources exploited should be immediately adjacent to a site's location. Using Van Thunen's concentric model as a conceptual device, Chisholm (1968) develops the idea that the bulk of any community's economic activities are conducted within one kilometer of the community (obviously, this does not apply to highly developed and centralized, industrially-oriented, urban centers) (see Appendix F).

Use of the catchment area can also permit us to examine the environmental setting closely. If for example the bulk of the vegetation within a site's catchment was suitable only as forage for grazing and browsing animals, it would be logical to infer that the site was located to maximize access to animal resources present. On the other hand if plant materials suitable for human consumption made up the greatest bulk of the resources contained within the catchment area, it would be logical to assume the site was located to exploit plant resources. A mix between the two is assumed to be indicative of a balance between plant and animal exploitation.

Nature of the Statistical Tests Used

Universes for both the Naval Oil Shale Reserve and the Duck Creek area were constructed based on the varying percentages of vegetational zones contained within each area. The method is much the same as described by Plog (1971:50-52).

On the basis of these constructed universes, a series of hypotheses concerning site location and the nature of the catchment area surrounding the site were formulated and subjected to a series of statistical tests.

The hypotheses and tests fell into three categories. The first involved hypotheses concerning site distribution in the abstract world. The principal test used was the nearest neighbor statistic. Because of methodological problems dealing with boundaries (Hodder and Orten 1976), no tests of significance were applied to this category.

The second category involved hypotheses comparing site location characteristics within the regional universe. Principal tests used were based on percentage point differences and chi-square testing. The chi-square test is particularly appropriate when it is essential to determine whether or not a particular distribution is normal. Levels of significance were considered to be at the .05 level (Yates 1974:187-189, 202-206).

The third category involved hypotheses dealing with relationships between site location and factors within the environments of the respective regions. Principal tests used were correlation tests, and considering the lack of linear mathematical data, Spearman's rank correlation coefficient seemed to be the most appropriate. Again, levels of significance to be determined by Z score testing were to be at the .05 level (Yates 1974:189-202).

Specific hypotheses to be tested and the tests used are set out below:

H_o 1: If the distance to water exerts no influence on archaeological site location decisions, then as distance to water increases there should be no significant change in archaeological site frequency.

H_A 1: If the distance to water exerts an influence on archaeological site location decisions, then as distance to water increases archaeological site frequency should decrease.

Statistical Test: Spearman's Rank Correlation.

H_O 2: If slope is not a factor in influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of slopes present in the region.

H_A 2: If slope is a factor influencing archaeological site location decisions, then archaeological sites should be found within a clearly defined range of slope angles.

Statistical Test: None, rather descriptive statistics in terms of mean and standard deviation. Since an infinite variety of slopes exist within the Piceance Basin, examination of individual site selection in descriptive terms is considered adequate to indicate preference. A total of 139 sites were used to develope the descriptive statistic.

A further test, Pearson's coefficient of variability, is used to compare slope variability in both the Naval Oil Shale Reserve and the Duck Creek/Corral Gulch regions.

H_o 3: If aspect is not a factor influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of headings present in the region.

H_A 3: If aspect is a factor influencing archaeological site location decisions, then archaeological sites should exhibit a marked preference for certain headings and an avoidance of others.

Statistical Test: Chi-square.

H_o 4: If the distribution of soils exerts no influence upon archaeological site location, then archaeological sites will be distributed over the landscape in a manner proportional to soil zone coverage.

H_A 4: If the distribution of soils exerts a marked effect upon archaeological site location, then archaeological sites will be distributed non-randomly with regard to soil zone coverage.

Statistical Test: Chi-square.

H_o 5: If the distribution of vegetation exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the landscape in a manner proportional to the vegetational zone coverage.

H_A 5: If the distribution of vegetation exerts a marked effect upon site location, then archaeological sites will be distributed non-randomly with regard to vegetational zone coverage.

Statistical Test: Chi-square.

H_o 6: If there is no significant similarity in the food preferences of man and the mule deer, then there should be little or no correlation between the foods consumed by both species.

H_A 6: If there is a significant similarity in the food preferences of man and the mule deer, then there should be a marked correlation between the foods consumed by both species.

Statistical Test: Spearman's Rank Correlation.

H_O 7: If variety as previously defined exerts no influence upon archaeological site location decisions, then an increase in variety will not produce an increase in archaeological site frequency.

H_A 7: If variety as previously defined exerts an influence on archaeological site location decisions, then an increase in variety should result in an increase in archaeological site frequency.

Statistical Test: Spearman's Rank Correlation.

H_O 8: If density as previously defined exerts no influence on archaeological site location decisions, then an increase in density will not produce an increase in archaeological site frequency.

H_A 8: If density as previously defined exerts an influence on site location decisions, then an increase in density should result in an increase in site frequency.

Statistical Test: Spearman's Rank Correlation.

H_o 9: If productivity as previously defined exerts no influence on site location decisions, then an increase in productivity will not produce an increase in site frequency.

H_A 9: If productivity as previously defined exerts an influence upon site location decisions, then an increase in productivity should result in an increase in site frequency.

Statistical Test: Spearman's Rank Correlation.

H_o 10: If there is no significant difference between the observed percentages of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit the same vegetational characteristics as the regional universe.

H_A 10: If there is significant difference between the observed percentage of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit different vegetational characteristics than that of the regional universe.

Statistical Test: Chi-square.

The hypotheses will be tested in the Naval Oil Shale Reserve and in the Duck Creek areas. Further, an attempt will be made to determine the role of productivity as a decisive factor in location decisions, particularly in those sites chosen for catchment analysis. Site catchments will also be evaluated for content with descriptive statistics being used to provide insights into the economic potentials of both regions. In Chapter VII, The Ethnographic Record, the statistical conclusions reached will be compared with the ethnographic record.

CHAPTER VI

ANALYSIS

Without testing the environmental model developed in Chapter IV is nothing more than an interesting set of hypotheses. In this chapter the hypotheses drawn from the model will be tested at three levels by various statistical devices.

The first level which deals with point-pattern analysis poses and answers questions about structure. Is site location a random or non-random phenomena. Hypotheses tested at this level deal with the nature and degree of randomness observed.

The second level involves the establishment of correlations between site location and specific factors within the immediate environment. Hypotheses tested at this level involve covariance and the establishment of correlation.

The third and final level of model testing, site catchment analysis, is less specific than either of the two preceding levels as it deals with evaluation of environmental factors that influence site location but are not necessarily adjacent to the site. Evaluation of these factors is inherently more qualitative than quantitative in nature.

Point Pattern Analysis

Point-pattern analysis is an analytical approach of increasing interest to archaeologists. Despite this interest the basic manipulative techniques involved have not been developed by archaeologists but by plant ecologists and geographers who are interested in the degree of departure from randomness that a given distribution of points may exhibit (Hodder and Orton 1976:30). Since distributions are considered to be the result of systematic forces at work, measurement of the degree of departure from randomness may indicate why and to what degree these systematic factors favor specific locations or areas over other locations or areas. Departure from randomness would then imply the presence of order or structure.

> Since it is highly unlikely that geographic distribution, particularly locational patterns involving human decisions, are the result of equally probable events, it is expected that most map patterns reflect some system or order (Dacey 1964:559).

Study of order or structure can only commence after determination has been made as to the nature of the distribution involved. If the distribution is not random, then and only then can questions be asked about the nature of the structure of the distribution. However, identification of structure does not mean anything has been explained.

Several techniques have been developed over the past few years to distinguish non-randomness from randomness. In general they can be divided into either quadrat methods or distance methods (Hodder and Orton 1976:33).

Quadrat methods involve the construction of a uniform grid of squares or rectangles, the noting of the number of observations within each grid, and the direct comparison of these observations with the Poisson distribution corresponding to some number of points by means of a goodness-of-fit test and the chi-square statistic (Hodder and Orton 1976:33-34). Problems posed by the use of the quadrat method involve the size of the quadrat used, shape of the quadrat, and the necessity of having a square or rectangular grid (Hodder and Orton 1976:36-38). Hodder and Orton (1976:38) feel that these limitations make the distance-based method preferable when dealing with archaeological data.

The most commonly used test based on distance was developed by Clark and Evans (1954). It involves measuring the distance which separates each site from its nearest neighbor. The value R_n is calculated where

$$R_n = 2\bar{d}\sqrt{\frac{n}{a}}$$

$\bar{d}$ is the mean distance between points and their nearest neighbor, a is the area concerned, and n is the number of points (Theakstone and Harrison 1970:61).

This test, known as the nearest-neighbor statistic, produces values for R_n that range from zero (maximum cluster) to 2.15 (maximum dispersion). A value of 1.00 indicates a random distribution.

An important limitation to this test is posed by the size of the area being studied. The same pattern of point distribution could conceivably range from "clustered" to "dispersed" depending on the size of the area being considered. Boundaries (seacoasts, escarpments, or artificial boundaries) beyond which measurements cannot be taken tend to produce greater values of R_n than would be expected if dealing with an infinite area.

The nearest-neighbor statistic was used as a test in both the Naval Oil Shale Reserve area and the Duck Creek-Corral Gulch area to determine the degree of departure from randomness.

The hypothesis tested states: departure from a state of randomness is indicative that some sort of structure or order influenced settlement or location of sites within the Piceance Basin.

Nearest-Neighbor Analysis: Naval Oil Shale Reserve

Area A	Number of Sites (n)	Mean Distance Between Points and Their Nearest Neighbor $\bar{d}$	R_n
14,392.55 Hectares	76	555.25 Meters	.81

R_n = .81 is indicative of a tendency to cluster. Map examination, however, shows two distributions (see site map; Kane 1973). In the northern portions of the Naval Oil Shale Reserve site location is essentially riverine, while in the southern portion of the Reserve site location is essentially upland. The stream-side, northern sites exhibit a departure from randomness to a marked degree with $R_n = .30$. The southern, upland sites also cluster but to a much lesser degree, $R_n = .83$. The difference may be due to terrain characteristics. The northern streams exhibit fairly broad, shallow valleys suitable for camp sites, while the southern streams are characterized by deep, steep, V-shaped valleys that are totally unsuitable for habitation (Kane, personal communication 1977, and personal inspection).

In either case there is a tendency for sites within the Naval Oil Shale Reserve to cluster and this tendency is more pronounced in the north.

Nearest-Neighbor Analysis: Duck Creek-Corral Gulch

Area A	Number of Sites (n)	Mean Distance Between Points and Their Nearest Neighbor $\bar{d}$	R_n
12,007.16 Hectares	130	460.66 Meters	.96

$R_n = .96$ indicates a very slight tendency to cluster, but with 1.00 indicating randomness, it certainly is not a marked tendency (see site map, Olson et al. 1975).

Since a state of non-randomness is present in the Naval Oil Shale Reserve, it can be assumed that the hypothesis (i.e., some sort of structure or order has influenced settlement or location) is sustained, at least for the Naval Oil Shale Reserve.

On the other hand the near-random value of R_n for the Duck Creek-Corral Gulch area of the Piceance Basin may be due to the boundary effect discussed by Hodder and Orton (1976) in which the value of R_n can vary from one extreme to the other depending upon the location of the boundary of the area being considered. Under these circumstances, the very slight trend away from true randomness may still be indicative of systematic factors at work whose effect is being masked by Hodder and Orton's boundary effect.

No tests of significance were attempted on these nearest neighbor tests because the significance tests evaluate the quantitative aspects of the statistic which may be due to boundary effect and not to the effect of site structure and location.

Tests of Factors Affecting Site Location

As Plog notes, determination of the importance of various factors that influence location of archaeological sites can be accomplished fairly simply:

> If a variable has no effect on the spatial distribution of the sites, then the ratio of the land surface covered by its various states to the total

> land surface would be equal to the ratio of the number of sites occurring in each of the land surface zones to total sites (1971:50).

Mapping the variable under consideration permits the establishment of a universe which can be consulted in the form of the null hypothesis (H_O)/Alternate (H_A) hypothesis dichotomy. Acceptance of the null hypothesis immediately rejects the role and the significance of the questioned factor in site location. On the other hand, rejection of the null hypothesis would confirm both the alternate hypothesis and by implication the role of that factor. Rejection or acceptance of the null hypothesis can best be accomplished with the use of chi-square.

A second but different sort of test can be applied to determine the importance of various factors affecting site location. For example, water is essential to human survival; therefore, its importance need not be tested per se. Rather, given the obvious importance of water, a different sort of question should be asked. Does distance from permanent water significantly affect site location? In this case the importance of the factor is assumed, and some aspect--distance, quality, or amount of the factor under consideration--is being tested. Under these circumstances correlation can become an effective test. In this section chi-square is used to test factors influencing site location. Spearman rank correlation is used to test characteristics of those factors which are assumed or have been demonstrated to be of importance in influencing site location.

Water as a Critical Factor in Site Location

While water has always been an important factor in determining how man distributes himself over the landscape, in semi-arid and arid lands the location of water becomes crucial to survival.

Reduced to a testable hypothesis, we have:

H_o 1: If the distance to water exerts no influence on archaeological site location decisions, then as distance to water increases there should be no significant change in archaeological site frequency.

H_A 1: If the distance to water exerts an influence on archaeological site location decisions, then as distance to water increases archaeological site frequency should decrease.

In the Naval Oil Shale Reserve distance to permanent water ranges from 0 meters (nine sites: 5GF 53, 5GF 55, 5GF 57, 5GF 66, 5GF 67, 5GF 71, 5GF 72, 5GF 83, and 5GF 95) to 250 meters (one site: 5GF 46) (see Table 10).

Correlation between distance and numbers of archaeological sites using Spearman rank correlation produced a correlation of $R_s = -0.87$ with a z-score of -3.90.

TABLE 10

DISTANCE OF SITES FROM PERMANENT WATER IN THE NAVAL OIL SHALE RESERVE PORTION OF THE PICEANCE BASIN OF COLORADO

DISTANCE FROM PERMANENT WATER IN METERS	NUMBER OF ARCHAEOLOGICAL SITES
0 - 5	9
5 - 10	17
10 - 15	13
15 - 20	5
20 - 25	6
25 - 30	2
30 - 35	6
35 - 40	0
40 - 45	5
45 - 50	0
50 - 55	6
55 - 60	0
60 - 65	1
65 - 70	0
70 - 75	1
75 - 80	1
80 - 85	2
85 - 90	0
90 - 95	0
95 - 100	0
100 - 105	1
105 - 250	1

The degree of correlation is very high and it is significant at the .01 level.

This means that as distance from permanent water increases, the number of archaeological sites tends to decrease. In the Naval Oil Shale Reserve this tendency is quite pronounced where average distance from permanent water to archaeological site is 21.4 meters and where 92 per cent of the archaeological sites are recovered within fifty meters of permanent water.

The situation in the Duck Creek area is slightly different. Distance here from permanent water ranges from zero meters (two sites: D.U. field numbers 75 and 105) to 1,260 meters (one site: D.U. field number 26) (all site numbers in Rio Blanco County are Denver University field numbers--see Olson et al. 1975) (Table 11).

Correlation between distance and numbers of archaeological sites using Spearman rank correlation produced a correlation of $R_S = 0.79$ with a z-score of -3.97. Again the degree of correlation is very high, and it is significant at the .01 level. Also as distance from permanent water increases, the number of archaeological sites tend to decrease. This tendency is not quite as pronounced as it is in the Naval Oil Shale Reserve, where distance from permanent water is measured in tens of meters; here measurement is in terms of hundreds of meters. Average distance from permanent water to an

TABLE 11

DISTANCE OF SITES FROM PERMANENT WATER IN THE DUCK CREEK PORTION OF THE PICEANCE BASIN OF COLORADO

DISTANCE FROM PERMANENT WATER IN METERS	NUMBER OF ARCHAEOLOGICAL SITES
0 - 50	2
50 - 100	6
100 - 150	7
150 - 200	11
200 - 250	9
250 - 300	6
300 - 350	10
350 - 400	6
400 - 450	4
450 - 500	5
500 - 550	7
550 - 600	1
600 - 650	1
650 - 700	0
700 - 750	0
750 - 800	2
800 - 850	0
850 - 900	1
900 - 950	0
950 - 1000	2
1000 - 1050	1
1050 - 1100	0
1100 - 1150	3
1150 - 1200	0
1200 - 1250	0
1250 - 1300	1

archaeological site is 372 meters and 86 per cent of the sites are within 550 meters of permanent water.

In both regions the null hypothesis is rejected and the alternate hypothesis is sustained.

Topography as a Factor

Measurements of slope angle and aspect of slope were taken of 61 sites in the Naval Oil Shale Reserve and 78 sites in the Duck Creek region. Data source for these measurements was U. S. Geological Survey sheets. Those used for the Naval Oil Shale Reserve were the 7.5 minute series (topographic) covering the Anvil Points quadrangle and the Rio Blanco Quadrangle. The Wolf Ridge and Square S Ranch quadrangles were used for the Duck Creek area.

Formulated as an hypothesis we have the following:

H_O 2: If slope is not a factor in influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of slopes present in the region.

H_A 2: If slope is a factor influencing archaeological site location decisions, then archaeological sites should be found within a clearly defined range of slope angles.

As noted in the last chapter, no tests were undertaken of this hypothesis. Instead descriptive statistics in terms of mean and standard deviation were used. With an infinite variety of slopes existing within the basin, examination in descriptive terms is considered not only adequate but practical to reject the null hypothesis even though it is not formally tested.

Vertical interval was forty feet on those maps covering the Naval Oil Shale Reserve, while the maps used for the Duck Creek area had a twenty foot vertical interval. This difference in vertical interval reflects the general character of the land forms. In the Naval Oil Shale Reserve, for example, it is possible to measure an elevation change of 1,000 feet in a horizontal distance of 7.3 miles (slope angle 2.59 per cent) (excluding erosional features), while in Duck Creek a 943 foot elevation change occurs in only 1.3 miles (slope angle 13.74 per cent). Slope angle preferences for both the Naval Oil Shale Reserve and the Duck Creek area are summarized in Table 12.

Pearson's coefficient of variability test,

$$V = \frac{100\,\sigma}{\bar{X}}$$

where V = Variability, σ = standard deviation, and $\bar{X}$ = mean value of factor being tested, converts variability to a percentage and shows that the Duck Creek area with

TABLE 12

SLOPE PREFERENCES OF ARCHAEOLOGICAL SITES LOCATED IN THE PICEANCE BASIN OF NORTHWEST COLORADO

AREA	NUMBER OF SITES (n)	MEAN SLOPE ANGLE DEGREES	STD DEV	MIN ANGLE	MAX ANGLE
Naval Oil Shale Reserve	61	8.93°	5.19°	2°	20°
Duck Creek	78	4.99°	3.71°	1°	15°

its smaller mean slope angle and its smaller standard deviation has 16.23 per cent greater variability than does the Naval Oil Shale Reserve.

Slope is only one aspect of terrain preference. In addition to measurement of slope angle, the aspect of the slope was also measured. Plotting the number of sites and their orientation on polar coordinate graph paper produces the following distributions (see Fig. 15 and 16).

The tested hypothesis is:

H_o 3: If aspect is not a factor influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of headings present in the region.

H_A 3: If aspect is a factor influencing archaeological site location decisions, then archaeological sites should exhibit a marked preference for certain headings and an avoidance of others.

Using the polar coordinate plots (Figs. 15 and 16) as the observed frequencies and a value of 1.64 sites and 2.17 sites per 10 degrees cell for the Naval Oil Shale Reserve and Duck Creek regions, respectively, Chi-square testing produces the following results (see Table 13).

TABLE 13

CHI-SQUARE TEST, ASPECT,
PICEANCE BASIN, COLORADO

Location	X^2 Value	Degrees of Freedom	Null Hypothesis
Naval Oil Shale Reserve	450.80	35	Rejected at .01 level
Duck Creek	79.54	35	Rejected at .01 level

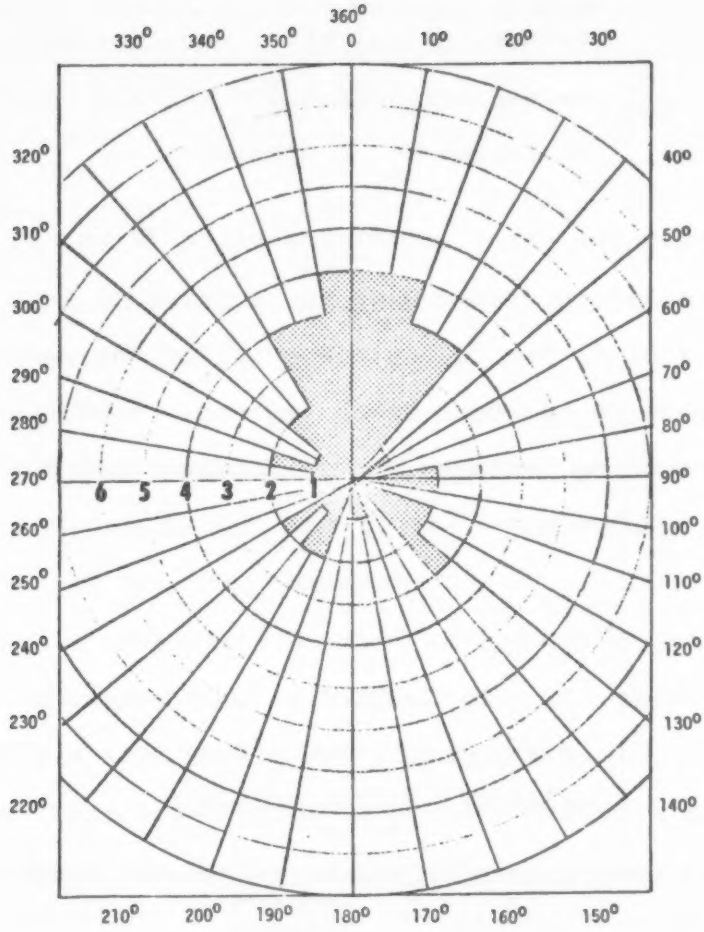


FIGURE 15

PREFERRED ASPECTS OF ARCHAEOLOGICAL SITES
LOCATED IN THE NAVAL OIL SHALE RESERVE
PORTION OF THE PICEANCE BASIN
OF NORTHWEST COLORADO

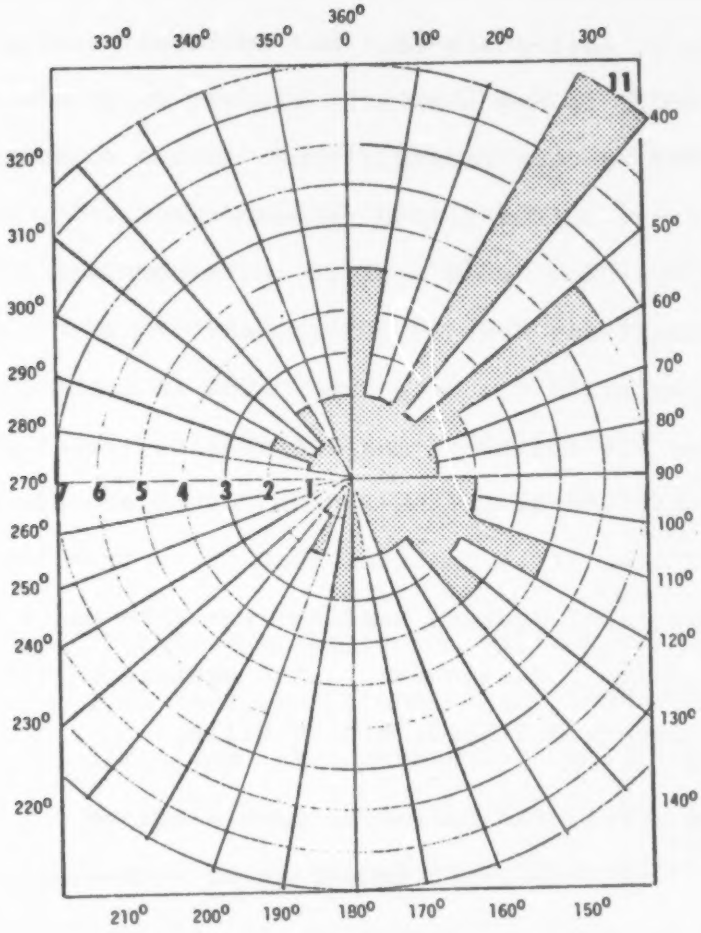


FIGURE 16

PREFERRED ASPECTS OF ARCHAEOLOGICAL SITES LOCATED IN THE DUCK CREEK PORTION OF THE PICEANCE BASIN OF NORTHWEST COLORADO

In the Naval Oil Shale Reserve there is a marked preference for north facing slopes with a secondary interest in east-south-east and southwest facing slopes. Use of south facing slopes is minimal as is use of west-south-west to west facing slopes. Slope selection seems to favor the cooler slopes (summer range).

In the Duck Creek area there is complete avoidance of southwest and west facing slopes. This is somewhat surprising since the Duck Creek area is defined as winter range and the southwest and west facing slopes should be the warmest slopes in the region. This anomaly is resolved when it is realized that it is from the west-south-west (247 degrees heading) that the major winter storms arrive. Consequently, the preference for slope is the protected leeside of the hills.

Soils as a Critical Factor in Site Location

Soil type does not appear to be a critical factor in site location. For example, all of the sites located south of Duck Creek, north of Corral Gulch, and west of Yellow Creek are located on the Aridic Argiborolls and Haploboralls association. These soils are too cold and probably too alkaline for successful agriculture, and their use today is restricted to rangeland (U.S.D.A. Handbook No. 436, 1975).

Sites east of Duck Creek and west of the Piceance Basin are located on the Eutroboralf, Rock Outcrop, and

Haploboroll association. Again this zone's use is restricted to rangeland and is not suitable for agriculture (U.S.D.A. Handbook No. 436, 1975).

All of the sites in the Naval Oil Shale Reserve are situated on a typic Cyroboroll and typic Cryoboralf association found at the higher elevations of the Piceance Basin. These soils are too cold and growing season is too short to permit any sort of agricultural activity (Fox 1973; U.S.D.A. Handbook No. 436, 1975).

Because of the ubiquitous nature of the soil distribution by region and the specific hypothesis which states:

> H_O 4: If the distribution of soils exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the land scope in a manner proportional to soil zone coverage.
>
> H_A 4: If the distribution of soils exerts a marked influence upon archaeological site location decisions, then archaeological sites will be distributed non-randomly with regard to soil zone coverage.

we can only accept the null hypothesis.

The only soils capable of supporting farming are the Ustifluvents and Fluvaquents (U.S.D.A. Handbook No.

436, 1975). These are found in the flood plains of the major drainages of the Basin. One site, 5RB 271, while not situated directly upon this soil, immediately overlooks a particularly wide part of the Piceance Creek flood plain. It is felt that the presence of these soil associations were a contributing factor in the selection of this site's location. Reasons for this assumption will be discussed in detail later in this chapter in the section dealing with site catchment analysis.

Distribution of Vegetation as a Factor Affecting Site Location

Natural vegetation provides the nutritional base upon which all animal life in the Basin is ultimately dependent. Determination as to whether or not the distribution of natural vegetation is a factor in site location can best be ascertained through testing of the specific hypothesis below.

H_O 5: If the distribution of vegetation exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the landscape in a manner proportional to the vegetational zone coverage.

H_A 5: If the distribution of vegetation exerts a marked effect upon site location, then

> archaeological sites will be distributed non-randomly with regard to vegetational zone coverage.

Areas to be tested are the Naval Oil Shale Reserve and the Duck Creek drainage (see Tables 14 and 15).

Five basic vegetational zone classifications were used for this test in the Naval Oil Shale Reserve. $X^2 = 62.60$ is significant at the .01 level with four degrees of freedom. The hypothesis is rejected; consequently, the distribution of vegetation does significantly affect the location of archaeological sites in the Naval Oil Shale Reserve.

The same null hypothesis is posed for site distribution in the Duck Creek area. $X^2 = 12.18$ is significant at both the .10 and .05 level with four degrees of freedom. It is rejected at the .01 level. Since the chosen level of significance is .05, the hypothesis is again rejected and the implication that distribution of vegetation has an effect on the location of sites is sustained.

Establishment of vegetation as a general factor in site location permits study of those specific aspects of vegetation that are crucial to determining site location. Vegetation consists of large numbers of plant species that are grouped into vegetational zones or communities. It is these zones that provide food for man and for the animals that man preys upon.

TABLE 14

CHI-SQUARE TEST OF THE ROLE OF VEGETATION IN INFLUENCING SITE LOCATION IN THE NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONES	PERCENTAGE OF COVER	SITES OBSERVED	SITES EXPECTED
Mixed Mountain Shrubland	30%	10	22.80
High Elevation Grasslands	13%	26	9.88
Douglas Fir & Aspen	20%	0	15.20
Bare Slope	5%	0	3.80
Upland Big Sage/ Grassland	32%	40	24.32

Number of sites (n) = 76

TABLE 15

CHI-SQUARE TEST OF THE ROLE OF VEGETATION IN INFLUENCING SITE LOCATION IN THE DUCK CREEK AREA, PICEANCE BASIN, COLORADO

ZONES	PERCENTAGE OF COVER	SITES OBSERVED	SITES EXPECTED
Pinon/Juniper	48.22%	24	19.77
Riparian	1.24%	0	.51
Mixed Mountain Shrubland	.82%	2	.34
Lowland Big Sage	17.99%	3	7.38
Upland Big Sage/ Mid Elevation/ Grassland	31.46%	12	12.90

Number of sites (n) = 41

A total of 395 vascular plant species have been recorded in the Piceance Basin (Ward et al. 1972; Ferchau 1973; Keammerer 1974) and are broken down in Table 16.

TABLE 16

NUMBER OF PLANTS AVAILABLE FOR HUMAN CONSUMPTION IN THE PICEANCE BASIN, COLORADO

	EDIBLE	NON-EDIBLE	TOTAL
Native	153	171	324
Exotic	34	37	71
Total	187	208	395

Numerical distribution of these plants into the conventional tree, shrub, and herbaceous layers is shown in Table 17 and Appendix A lists the contents by species of these layers. Appendix A also identifies which species are native and which are exotic, which species are consumed by human beings and which by mule deer.

TABLE 17

DISTRIBUTION OF VASCULAR PLANTS BY COMMUNITY LAYER WITHIN THE PICEANCE BASIN

	TOTAL NO. NATIVE PLANTS	TOTAL NO. EXOTIC PLANTS	*TOTAL NO. EDIBLE PLANTS HUMAN BEINGS	*TOTAL NO. EDIBLE PLANTS MULE DEER
Tree Layer	14	4	8	10
Shrub Layer	49	1	30	40
Herbaceous Layer	337	66	115	206

*Refers only to plants native to the area and excludes exotics.

NOTE: No totals are attempted since several species can be found in more than one layer. Quercus gambelii is a classic example, being found both in the tree and shrub layer.

Needless to say, the edible species consumed by either human beings or mule deer are not evenly distributed throughout the twelve vegetational zones described in Chapter II. The bar graph in Figure 17 pictorially represents the distribution by zone of plants considered edible by human beings.

Figure 18 shows a parallel bar graph for the number of species available for consumption by mule deer distributed by zone.

Visual inspection of the two graphs reveals a reasonable degree of similarity. In general those zones with a high quantity of edible species for mule deer also exhibit a high quantity of edible species for people.

Use of Spearman rank correlation to compare the ranking of the two sets of data permits a direct comparison of similarity.

H_O 6: If there is no significant similarity in the food preferences of man and the mule deer, then there should be little or no correlation between the foods consumed by both species.

H_A 6: If there is a significant similarity in the food preferences of man and the mule deer, then there should be a marked correlation between the foods consumed by both species.

FIGURE 17

NUMBER OF PLANTS CONSIDERED EDIBLE BY HUMAN BEINGS BY VEGETATION ZONE IN THE PICEANCE BASIN, COLORADO

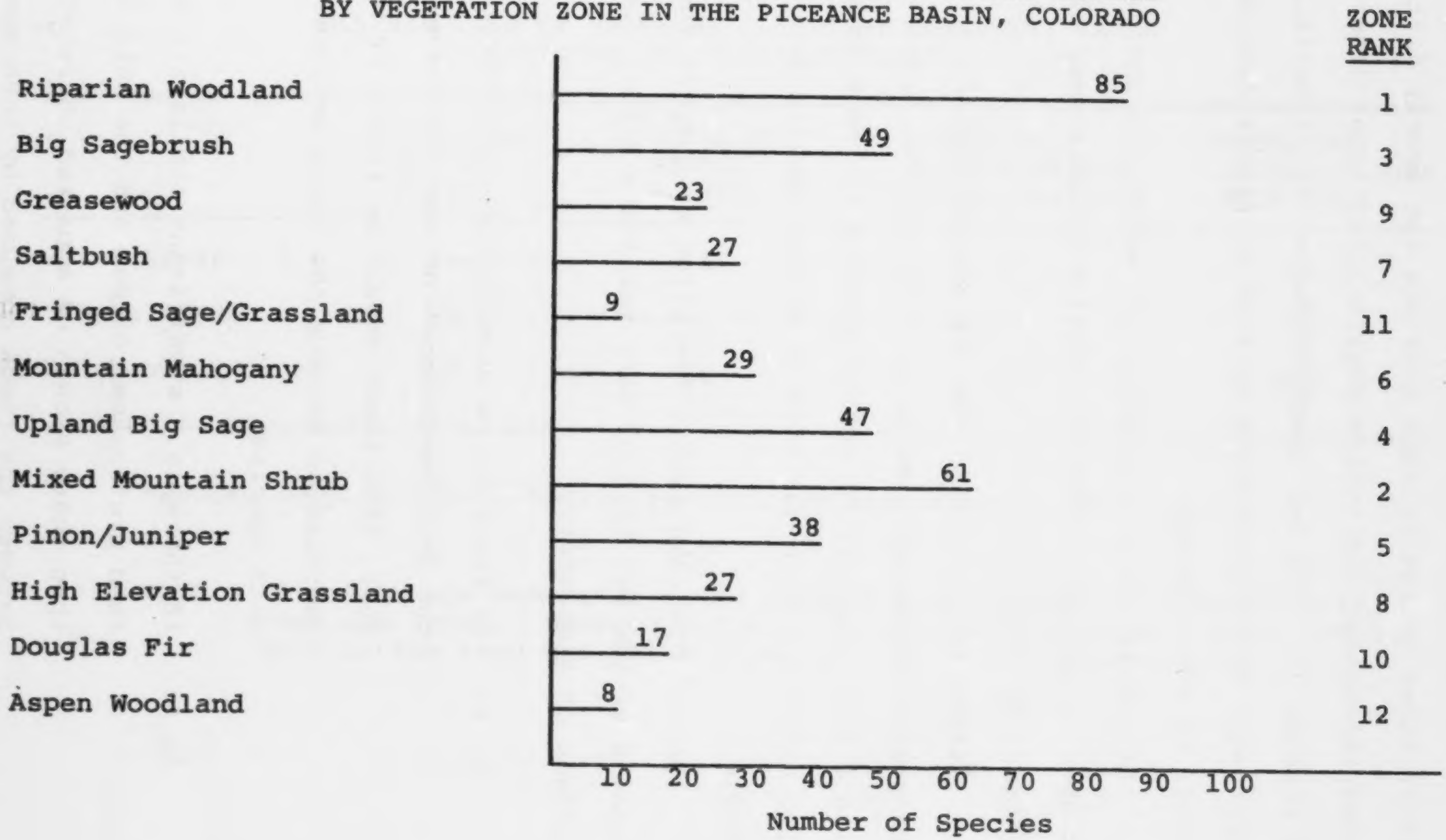
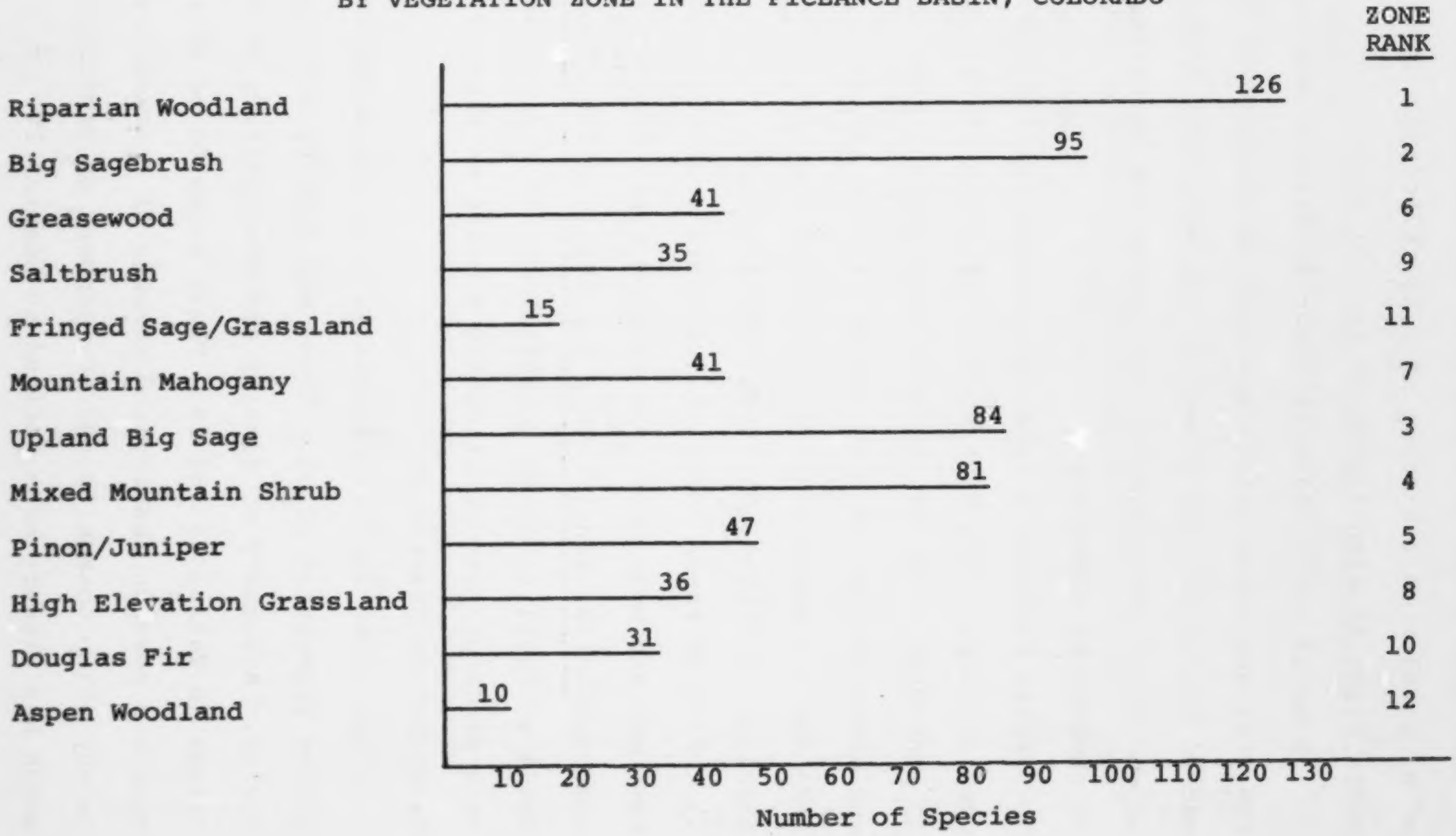


FIGURE 18

NUMBER OF PLANTS CONSIDERED EDIBLE BY MULE DEER
BY VEGETATION ZONE IN THE PICEANCE BASIN, COLORADO



In this case there is a positive correlation coefficient of $R_s = .93$ with a z-score of 2.85 indicating that this correlation is significant at the .01 level.

Even if the herbaceous layer is deleted and only the tree and shrub layers are used to approximate the marked preference for browse of the mule deer (Fig. 19), we can still see a similar pattern in the relationship of numbers of species per zone.

Again Spearman's rank correlation coefficient was used to compare the distribution of human edible species by zone with those of the mule deer derived from tree and shrub layers. A high degree of correlation, $R_s = +.93$ and a z-score of 3.08 indicating a correlation significant at the .01 level, was achieved.

Both of these correlations would seem to indicate that man and mule deer tend to find their food in the same vegetation zones. Thus the distribution of plants tends to facilitate the establishment of a man/animal or a predator/prey relationship similar to those already described in Chapter IV.

Two other factors besides variety characterize the twelve vegetation zones. These are density and productivity. A summary of density and productivity is contained in Tables 18 and 19. There seems to be no relationship between density and numbers of species present in any given community and the concept of productivity which has already been defined in Chapter IV.

FIGURE 19

SPECIES VARIETY IN THE TREE AND SHRUB LAYER OF THE PICEANCE BASIN, COLORADO

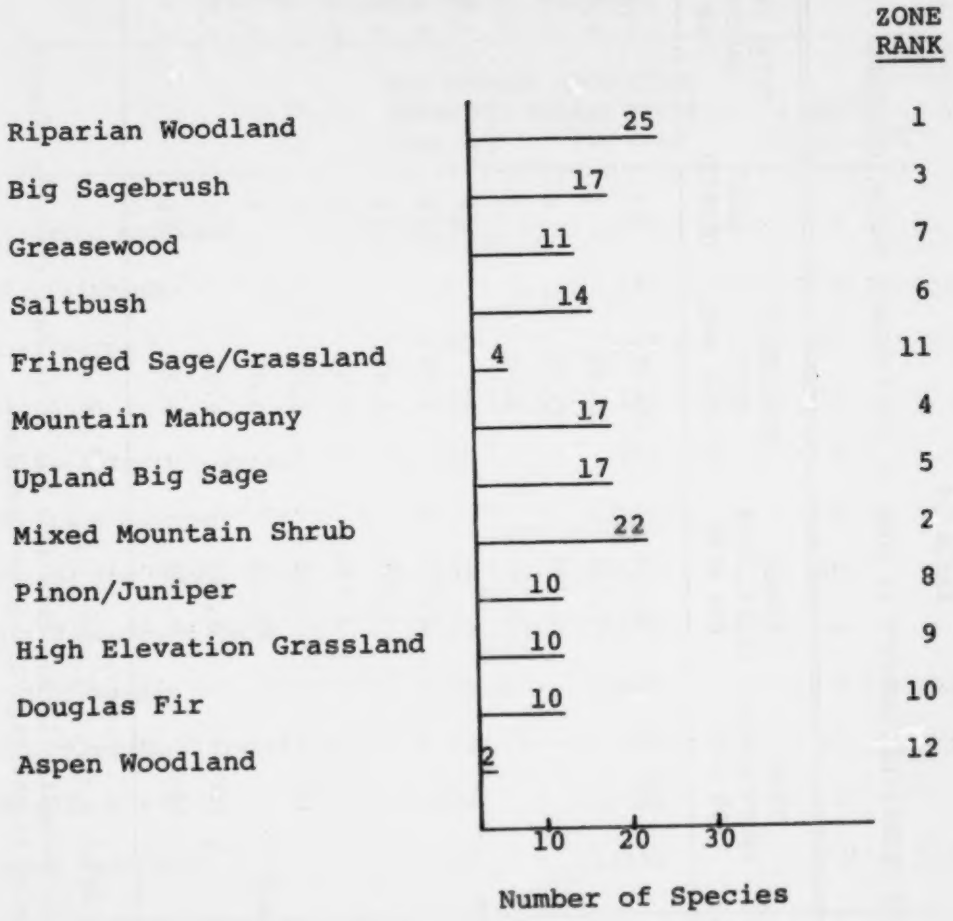


TABLE 18

SUMMARY OF VEGETATION DENSITY BY ZONE IN THE PICEANCE BASIN, COLORADO

	TREES INDIVIDUALS PER ACRE	SHRUBS INDIVIDUALS PER ACRE	HERBACEOUS COVER % TOTAL AREA	RANK DENSITY	TOTAL INDIVIDUAL TREES/SHRUBS PER ACRE
Riparian Woodland	295	2,121	26.3%	12	2,416
Big Sagebrush		5,081	15.0%	5	5,081
Greasewood		3,135	35.0%	8	3.135
Saltbush		3,341	4.0%	7	3,341
Fringed Sage/Grassland	*	*	*	10	3,000 est.
Mountain Mahogany		8,241	2.0%	2	8.241
Upland Big Sage		5,349	12.6%	6	5.349
Mixed Mountain Shrub	5	8,931	15.5%	1	8,936
Pinon/Juniper	119	3,121	2.5%	4	3.240
High Elevation Grassland		3,150	23.0%	9	3,150
Douglas Fir	210	5,592	6.0%	3	5,802
Aspen Woodland	194	5,399	29.0%	11	5,418

(After Keammerer 1974)

*No numerical data is available for this zone but it is felt that the closest analogous community is the High Elevation Grassland.

TABLE 19

PRODUCTIVITY OF THE VEGETATION ZONES OF THE PICEANCE BASIN, COLORADO

	NET PRIMARY PRODUCTION GRAMS PER SQUARE METER Per Day	NET PRIMARY PRODUCTION GRAMS PER SQUARE METER Per Year	RANK PRODUCTION
Riparian Woodland	2.74	1,000	5
Big Sagebrush	.50	182	8
Greasewood	.41	149	11
Saltbush	.41	149	12
Fringed Sage/Grassland	.50	182	9
Mountain Mahogany	2.74	1,000	6
Upland Big Sage	.50	182	10
Mixed Mountain Shrub	2.74	1,000	4
Pinon/Juniper	5.00	1,825	2
High Elevation Grassland	1.22	446	7
Douglas Fir	8.71	3,180	1
Aspen Woodland	4.27	1,560	3

After Odum 1959:68-87

Characteristics of Vegetation Affecting Site Location

Since vegetation does affect site location, the next question to be asked is what aspect of vegetation--variety, density, or productivity--most significantly affects site location.

The statistical device used is the Spearman rank correlation coefficient because the data being tested is not linear. This device requires the establishment of rankings of the two factors being considered. The table below outlines the regions being tested, the number of archaeological sites within each zone, and the ranking of zones by archaeological site content. This data is derived from the vegetation maps compiled from aerial photography (see Table 20).

TABLE 20

RANKING OF VEGETATIONAL ZONES BY NUMBER OF ARCHAEOLOGICAL SITES, NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONES	NUMBER OF SITES	RANKING OF ZONES
Mixed Mountain Shrubland	10	3
High Elevation Grassland	26	2
Douglas Fir/Aspen	0	4
Upland Big Sage/Grassland	40	1
Bare Slope	0	5

TABLE 21

RANKING OF VEGETATIONAL ZONES BY NUMBER OF ARCHAEOLOGICAL SITES, DUCK CREEK AREA, PICEANCE BASIN, COLORADO

ZONES	NUMBER OF SITES	RANKING OF ZONES
Pinon/Juniper	24	1
Riparian	6	5
Mixed Mountain Shrub	2	4
Lowland Big Sage	3	3
Upland Big Sage/ Mid Elevation/Grassland	12	2

TABLE 22

RANKING OF VEGETATIONAL ZONES BY VEGETATION CHARACTERISTIC NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONES	RANK VARIETY	RANK DENSITY	RANK PRODUCTIVITY
Mixed Mountain Shrub	1	1	2
High Elevation Grass	2	4	3
Douglas Fir/Aspen	3	2	1
Upland Big Sage/ Grassland	4	3	4
Bare Slope	5	5	5

TABLE 23

RANKING OF VEGETATIONAL ZONES BY VEGETATION CHARACTERISTIC, DUCK CREEK AREA, PICEANCE BASIN, COLORADO

ZONES	RANK VARIETY	RANK DENSITY	RANK PRODUCTIVITY
Pinon/Juniper	5	2	1
Riparian	1	5	3
Mixed Mountain Shrub	2	1	2
Lowland Big Sage	4	3	4
Upland Big Sage/ Mid Elevation/ Grassland	3	4	5

Results of the correlation tests are not conclusive. In the Naval Oil Shale Reserve area the results are as follows:

FACTOR: Variety (see Tables 20 and 22)

HYPOTHESIS:

H_o 7: If variety as previously defined exerts no influence upon archaeological site location decisions, then an increase in variety will not produce an increase in archaeological site frequency.

H_A 7: If variety as previously defined exerts an influence on archaeological site location decisions, then an increase in variety should result in an increase in archaeological site frequency.

CORRELATION: $R_s = -0.10$ with a z-score of -0.20

CONCLUSIONS: A low degree of correlation at a very low level of significance. It could occur by chance.

FACTOR: Density (see Tables 20 and 22)

HYPOTHESIS:

H_O 8: If density as previously defined exerts no influence on archaeological site location decisions, then an increase in density will not produce an increase in archaeological site frequency.

H_A 8: If density as previously defined exerts an influence on site location decisions, then an increase in density should result in an increase in site frequency.

CORRELATION: $R_s = -0.60$ with a z-score of -1.20

CONCLUSIONS: A negative correlation inherently makes sense; people do not live in dense thickets. The z-score indicates that chance could also be a factor.

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FACTOR: Productivity (see Tables 20 and 22)

HYPOTHESIS:

H_O 9: If productivity as previously defined exerts no influence on site location decisions, then an increase in productivity will not produce an increase in site frequency.

H_A 9: If productivity as previously defined exerts an influence upon site location decisions, then an increase in productivity should result in an increase in site frequency.

CORRELATION: $R_s = -0.40$ with a z-score of -0.80

CONCLUSIONS: The hypothesis is not sustained and the z-score again indicates chance may be a critical factor.

The situation is not appreciably different in the Duck Creek area.

FACTOR: Variety (see Tables 21 and 23)

HYPOTHESIS:

H_O 7: If variety as defined above exerts no influence upon archaeological site location decisions, then an increase in variety will not produce an increase in archaeological site frequency.

H_A 7: If variety as defined above exerts an influence on archaeological site location decisions, then an increase in variety should result in an increase in archaeological site frequency.

CORRELATION: $R_s = -0.90$ with a z-score of -1.80. This score is significant at the .05 level.

CONCLUSIONS: A very high negative correlation indicating a situation contrary to the hypothesis. As the species variety of a zone increases, the number of archaeological sites tend to decrease.

FACTOR: Density (see Tables 21 and 23)

HYPOTHESIS:

H_o 8: If density as defined above exerts no influence on archaeological site location decisions, then an increase in density will not produce an increase in archaeological site frequency.

H_A 8: If density as previously defined exerts an influence on site location decisions, then an increase in density should result in an increase in site frequency.

CORRELATION: $R_s = 0.30$ with a z-score of .60

CONCLUSIONS: The hypothesis is sustained but the correlation made is low and the z-score indicates chance could be a major problem.

FACTOR: Productivity (see Tables 21 and 23)

HYPOTHESIS:

H_o 9: If productivity as previously defined exerts no influence on site location decisions, then an increase in productivity will not produce an increase in site frequency.

H_A 9: If productivity as previously defined exerts an influence upon site location decisions, then an increase in productivity should result in an increase in site frequency.

CORRELATION: $R_s = +.10$ with a z-score of +0.20

CONCLUSIONS: The correlation is too low and chance is too great a factor to place any significance in the correlation.

Only one of the above correlations, that of variety in Duck Creek, is really informative. It implies that variety does not determine the location of archaeological sites.

At first glance the different correlations of -0.6 and +0.3 for the Naval Oil Shale Reserve and Duck Creek respectively seem contradictory. However, density in the Naval Oil Shale Reserve is high because of the nature of the cover. Juneberry and oakbrush form dense, impenetrable thickets while density in the Duck Creek area is based mainly on stands of pinon and juniper that provide adequate open spaces easily penetrated by man.

Productivity is a surprise. It seems logical to assume that if variety was being rejected, then productivity should be selected, but this does not seem to be the case. Table 19 shows that the amount of difference between zones in productivity, measured in terms of net primary production, is often slight. While one zone may be slightly more productive than another, the zone of lesser productivity may have greater area. Consequently, its total biomass output may be greater and therefore more economical to exploit.

Using the percentage of cover column in Tables 24 and 25, and multiplying those percentages by net primary production (NPP) per day, we can derive a productivity area index (P/AI) (P/AI = A x NPP/day). Ranking of the zones according to the Productivity Area Index (P/AI) and correlating these ranks with the distribution of archaeological sites produces the following results.

In the Naval Oil Shale Reserve there is no strong correlation of any type, and it is interesting to note that the most productive zone, Douglas Fir and Aspen, is devoid of archaeological sites. The second most productive zone, the Shrub zone, has ten sites or 13 per cent of the total archaeological inventory, and it occupies thirty per cent of the total area. This corresponds well to the negative correlation achieved when density was calculated for the Naval Oil Shale Reserve.

TABLE 24

PRODUCTIVITY/AREA INDEX OF THE VEGETATION ZONES OF THE NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONE	PERCENTAGE OF COVER	NPP	P/A I	RANK	NUMBER OF SITES	RANK
Mixed Mountain Shrub	30	2.74	82.20	2	10	3
High Elevation Grass	13	1.22	15.86	4	26	2
Douglas Fir/ Aspen	20	8.71	174.20	1	0	4
Upland Big Sage/ Grassland	32	.50	16.00	3	40	1
Bare Slope	5	0	0	5	0	5

$R_s = +.10$

$z = .20$

TABLE 25

PRODUCTIVITY/AREA INDEX OF THE VEGETATION ZONES OF THE DUCK CREEK AREA, PICEANCE BASIN, COLORADO

ZONE	PERCENTAGE OF COVER	NPP	P/A I	RANK	NUMBER OF SITES	RANK
Pinon/Juniper	48.22	5.00	241.10	1	24	1
Riparian	1.24	2.74	3.40	4	0	5
Mixed Mountain Shrub	.82	2.74	2.25	5	2	4
Lowland Big Sage	17.99	.50	9.00	3	3	3
Upland Big Sage/ Mid Elevation/ Grassland	31.46	.50	15.73	2	12	2

R_s = +.90

z = -.80 and is significant at the .05 level

We are still left with the fact that fifty per cent of the area of the Naval Oil Shale Reserve, which accounts for 87 per cent of the total productivity, accounts for only thirteen per cent of the total archaeological inventory. This implies that productivity of the vegetation zones does not directly affect site location in the Naval Oil Shale Reserve.

Site location is highly correlated with productivity in the Duck Creek area with 59 per cent of the sites occurring in the zone with the highest productivity index. It is reasonable then to assume that productivity is a major factor in site location determination in the Duck Creek area.

Site Catchment Analysis and Qualitative Evaluation of Vegetation

Sites are not always located in direct association with the resource being exploited. Some resources such as animals will even evacuate an area when man moves in. Under these conditions the correlation of sites with specific resources is often low and the levels of significance contain large elements of doubt.

To cope with this problem a simple technique was devised that would permit study and evaluation of the importance of resources that were proximal to but not in direct association with the site.

A series of randomly selected sites (twenty per cent sample in both the Naval Oil Shale Reserve and Duck

Creek region) chosen from those previously plotted on the vegetation maps were circumscribed by a circle with a 1,000 meter radius. It is felt that this device meets the locational implications of plant exploitation strategies as plant resources should be immediately adjacent to a site's location. Using Von Thunen's concentric model as a conceptual device, Chisholm (1968) develops the notion that the bulk of any community's economic activities are conducted within one kilometer of the community. Within this catchment area the area of each vegetational zone was measured and expressed as a percentage of the catchment area. This permits direct comparison with the regional universe already calculated for both the Naval Oil Shale Reserve and the Duck Creek areas. All measurements were taken with a polar planimeter (see Appendix F).

Universes used in these tests are slightly different from those previously used. Since some of the catchment areas constructed in the Naval Oil Shale Reserve include areas off the escarpment, the area beyond the escarpment and bounded by the Naval Oil Shale Reserve vegetation map is included in the universe. Universes used in catchment analysis are included in Tables 26 and 27.

These universe percentages were then compared with the percentages contained within each site's catchment area. Comparison was made in the form of a testable hypothesis.

TABLE 26

EXPECTED CATCHMENT UNIVERSE, NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONE	PERCENTAGE OF AREA
Mixed Mountain Shrubland	26%
Douglas Fir/Aspen Woodlands	18%
Upland Big Sagebrush Shrubland	6%
High Elevation Grasslands	11%
Hillside Fringed Sage and Grassland	22%
Bare Slope	4%
Boundary Beyond Escarpment	13%

TABLE 27

EXPECTED CATCHMENT UNIVERSE, DUCK CREEK, PICEANCE BASIN, COLORADO

ZONE	PERCENTAGE OF AREA
Scattered Pinon/Juniper	3.54%
Pinon/Juniper	44.68%
Mid Elevation Sage	31.46%
Riparian	17.99%
Mixed Mountain Shrubland	.82%
Cultivated Hay	1.24%

H_O 10: If there is no sigificant difference between the observed percentages of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit the same vegetational characteristics as the regional universe.

H_A 10: If there is significant difference between the observed percentage of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit different vegetational characteristics than that of the regional universe.

Rejection of the null hypothesis occurs in all but one (DU# 75) of the sample sites. Therefore the catchment areas of eighteen of the nineteen sample sites are significantly different than the universe. This indicates that the distribution of vegetation within the catchment is a significant factor in site location.

Previous tests of the variety, density, and productivity seem to indicate that the productivity/area relationship offers the most promising explanation for site location. While the $R_s = +.90$ correlation of the Duck Creek area is most convincing, the $R_s = +.10$ correlation from the Naval Oil Shale Reserve is too low (see Tables 28 and 29).

TABLE 28

CHI-SQUARE TEST OF THE DISTRIBUTION OF VEGETATION WITHIN THE SITE CATCHMENTS OF THE NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

SITE NUMBER	DEGREES OF FREEDOM	X^2	HYPOTHESIS STATUS	LEVEL OF SIGNIFICANCE
5GF 29	6	377.10	Rejected	.01
5GF 31	6	58.70	Rejected	.01
5GF 35	6	311.95	Rejected	.01
5GF 42	6	39.49	Rejected	.01
5GF 45	6	113.37	Rejected	.01
5GF 48	6	189.15	Rejected	.01
5GF 54	6	127.82	Rejected	.01
5GF 62	6	289.52	Rejected	.01
5GF 76	6	72.10	Rejected	.01
5GF 78	6	315.91	Rejected	.01

TABLE 29

CHI-SQUARE TEST OF THE DISTRIBUTION OF VEGETATION WITHIN THE SITE CATCHMENTS OF THE DUCK CREEK REGION, PICEANCE BASIN, COLORADO

SITE NUMBER	DEGREES OF FREEDOM	X^2	HYPOTHESIS STATUS	LEVEL OF SIGNIFICANCE
5RB 23	5	18.86	Rejected	.01
5RB 42	5	150.47	Rejected	.01
5RB 75	5	7.32	Accepted	---
5RB 76	5	33.08	Rejected	.01
5RB 77	5	15.15	Rejected	.01
5RB 85	5	44.19	Rejected	.01
5RB 96	5	26.38	Rejected	.01
5RB 134	5	25.73	Rejected	.01
5RB 271	5	160.22	Rejected	.01

Again, using the percentage of cover (A) contained within the catchment area and multiplying it by the net primary production per day (N_{pp}), we can derive a productivity area index (P/AI), (P/AI/catchment = A/catchment x N_{pp}/zone).

Naval Oil Shale Reserve

Let us assume a catchment that matches the basic universe in the Naval Oil Shale Reserve. This means the vegetation within the catchment will be distributed in the following manner (see Table 30).

On the basis of area percentages a productivity area index can be calculated to produce a total productivity index for the catchment area. It would, of course, be entirely practical to multiply the area in square meters times the net primary productivity and attain similar results, proportions, and rankings for correlation tests, the only difference being the large numbers that would result. For example, the universe catchment has a 1,000 meter radius and its total area is 3,141,592,654 square meters. Since Douglas fir and aspen represent eighteen per cent of the area within the defined catchment, Douglas fir and aspen occupy 565,486.6777 square meters within the catchment. Multiplying this by N_{pp} of 8.71 produces a net primary production per day of 4,925,388.963 grams. Use of percentages eliminates the astronomical numbers but retains the internal relationships.

TABLE 30

EXPECTED CATCHMENT PRODUCTIVITY, NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

ZONE	PRODUCTIVITY gms/m^2/day	AREA %	PRODUCTIVITY/AREA INDEX (P/AI)
Mixed Mountain Shrubland	2.74	26	71.24
Douglas Fir/Aspen Woodlands	8.71	18	156.78
Upland Big Sagebrush Shrubland	.50	6	3.00
High Elevation Grassland	1.22	1	35.42
Hillside Fringed Sage and Grassland	.50	22	11.00
Bare Slope	0	4	0
Boundary	0	13	0
		TOTAL P.I.	277.44

Comparison between the universe catchment and the chosen site catchment can easily be calculated by repeating the steps outlined above in Table 30 and is displayed in Table 31.

It is interesting to note that nine of the ten sites are more productive than the universe. In other words people were selecting sites so as to maximize return.

It is also useful to note where the highest productivity lies within each catchment. In nine out of ten sites the Douglas fir/aspen combination has the highest biomass productivity and on the average accounts for 61.77 per cent of the productivity. Shrub cover is second and accounts on the average for 28.48 per cent.

In terms of food productivity for human beings the Douglas fir/aspen zone ranks low while the shrubland and upland sage community ranks high. For the mule deer the situation is reversed. The shrub zone is attractive to both species. Under these circumstances evaluation of the randomly selected sites in terms of human consumption/mule deer consumption is possible (see Table 32).

Mule deer consumption is derived from two zones, the Douglas fir/aspen combination and the High Elevation Grassland. Kufeld et al. (1973) note large-scale grass consumption for mule deer on a seasonal basis.

On the average then the catchments contain almost a two-to-one preference for mule deer forage, and in

TABLE 31

AREA/PRODUCTIVITY OF SITES IN THE NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

SITE NO.	MIXED MOUNTAIN SHRUBLAND	DOUGLAS FIR/ASPEN WOODLAND	UPLAND BIG SAGEBRUSH SHRUBLAND	HIGH ELEVATION GRASSLANDS	HILLSIDE FRINGED SAGE AND GRASSLAND	BARE SLOPE	BOUNDARY	TOTALS	UNIVERSE PERCENTAGE
5GF 29									
% cover	66.00	14.00	0	9.00	11.00	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	180.84	121.94	0	10.98	6.50	0	0	320.26	115.43
% Prod.	56.47	38.08	0	3.43	2.03	0	0		
5GF 31									
% cover	43.00	37.00	5.00	7.00	8.00	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	117.82	322.27	2.50	8.54	4.00	0	0	455.13	164.05
% Prod.	25.89	70.81	.55	1.88	.88	0	0		
5GF 35									
% cover	7.00	27.00	46.00	8.00	0	0	12	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	19.18	235.17	23.00	9.76	0	0	0	287.11	103.49
% Prod.	6.68	81.91	8.01	3.40	0	0	0		
5GF 42									
% cover	22.00	28.00	0	12.00	37.00	0	0	99%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	60.28	243.88	0	14.64	18.50	0	0	337.30	121.58
% Prod.	17.87	72.30	0	4.34	5.48	0	0		

TABLE 31 (continued)

SITE NO.	MIXED MOUNTAIN SHRUBLAND	DOUGLAS FIR/ASPEN WOODLAND	UPLAND BIG SAGEBRUSH SHRUBLAND	HIGH ELEVATION GRASSLANDS	HILLSIDE FRINGED SAGE AND GRASSLAND	BARE SLOPE	BOUNDARY	TOTALS	UNIVERSE PERCENTAGE
5GF 45									
% cover	35.00	27.00	26.00	12.00	0	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	95.90	235.17	13.00	14.64	0	0	0	358.71	129.29
% Prod.	26.73	65.56	3.62	4.08	0	0	0		
5GF 48									
% cover	25.00	20.00	37.00	12.00	6.00	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	68.50	174.20	18.50	14.64	3.00	0	0	278.84	100.50
% Prod.	24.57	62.47	6.63	5.25	1.08	0	0		
5GF 54									
% cover	25.00	31.00	29.00	0	15.00	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	68.50	270.01	14.50	0	7.50	0	0	360.51	129.94
% Prod.	19.00	74.90	4.02	0	2.08	0	0		
5GF 62									
% cover	17.00	24.00	45.00	0	14.00	0	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	46.58	209.04	22.50	0	7.00	0	0	285.12	102.77
% Prod.	16.34	73.32	7.89	0	2.46	0	0		

TABLE 31 (continued)

SITE NO.	MIXED MOUNTAIN SHRUBLAND	DOUGLAS FIR/ASPEN WOODLAND	UPLAND BIG SAGEBRUSH SHRUBLAND	HIGH ELEVATION GRASSLANDS	HILLSIDE FRINGED SAGE AND GRASSLAND	BARE SLOPE	BOUNDARY	TOTALS	UNIVERSE PERCENTAGE
5GF 76									
% cover	49.00	16.00	5.00	24.00	0	6	0	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	134.26	139.36	2.50	29.28	0	0	0	205.40	110.08
% Prod.	43.96	45.63	.82	9.59	0	0	0		
5GF 78									
% cover	23.00	5.00	46.00	3.00	0	0	23	100%	
gms/m^2/day	2.74	8.71	.50	1.22	.50	0	0		
Totals	63.02	43.55	.23	3.66	0	0	0	133.23	48.02
% Prod.	47.30	32.69	17.26	2.75	0	0	0		
$\bar{X}$ % Prod.	28.48	61.77	4.88	3.47	1.40	0	0		
High	56.47	81.91	17.26	9.59	5.48	0	0		
Low	6.68	32.69	0	0	0	0	0		
σ	15.73	16.95	5.38	2.77	1.73	0	0		

TABLE 32

COMPARISON OF CATCHMENT PRODUCTIVITY IN TERMS OF CONSUMPTION BY MAN AND MULE DEER IN THE NAVAL OIL SHALE RESERVE, PICEANCE BASIN, COLORADO

SITE NO.	PERCENTAGE OF CATCHMENT PRODUCTIVITY CONSUMED BY HUMANS	PERCENTAGE OF CATCHMENT PRODUCTIVITY CONSUMED BY MULE DEER
5GF 29	56.47	43.53
5GF 31	26.44	73.56
5GF 35	14.69	85.31
5GF 42	17.87	82.13
5GF 45	30.35	69.65
5GF 48	31.20	68.80
5GF 54	24.02	76.98
5GF 62	24.23	75.77
5GF 76	44.78	55.25
5GF 78	64.56	35.44
	$\bar{X}$ = 33.46	$\bar{X}$ = 66.64

those sites where mule deer forage predominates this preference is even higher (72.25 per cent of catchment on the average is forage for mule deer) with a 7:3 ratio present.

The implication of these figures seems clear. Sites in the Naval Oil Shale Reserve were located in such a manner as to maximize access to the mule deer summering on the Reserve.

Duck Creek Area

Catchment evaluation of the Duck Creek area does not produce identical results. The basic universe catchment takes on the following aspect (see Table 33).

As in the case of the Naval Oil Shale Reserve, comparison can be made between the universe catchment and the randomly chosen site catchments (see Table 34).

The situation in Duck Creek is different from that of the Naval Oil Shale Reserve. Here four sites exceed the universe in productivity. It is obvious that the tendency to maximize return within the catchment areas found within the Naval Oil Shale Reserve is not present in the Duck Creek area.

Examination of vegetation zone productivity within the catchment should indicate what aspects of productivity of the Duck Creek region were important to man. On the average the pinon/juniper zone accounts for 82.56 per cent of the catchment productivity with the fringed

TABLE 33

EXPECTED CATCHMENT PRODUCTIVITY, DUCK CREEK AREA, PICEANCE BASIN, COLORADO

ZONE	PRODUCTIVITY gms/m^2/day	AREA %	PRODUCTIVITY/AREA INDEX (P/AI)
Pinon/Juniper	5.00	48.22	241.10
Cultivated Hay	2.74	1.24	3.40
Upland Big Sage/ Mid-Elevation Sagebrush/ Grassland	.50	31.46	15.73
Big Sagebrush Shrubland (Bottomland)	.50	17.99	9.00
Mixed Mountain Shrubland	2.74	1.35	3.70
		TOTAL PI	272.93

TABLE 34
AREA/PRODUCTIVITY OF SITES IN THE DUCK CREEK AREA, PICEANCE BASIN, COLORADO

SITE NO.***	PINON/ JUNIPER	CULTIVATED HAY	UPLAND BIG SAGE/ MID-ELEVATION SAGEBRUSH	BIG SAGEBRUSH SHRUBLAND (BOTTOMLAND)	MIXED MOUNTAIN SHRUBLAND	TOTALS	UNIVERSE PERCENTAGE
23							
% cover	49.00	0	20.00	31.00	0	100%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	245.00	0	10.00	15.50	0	270.50	99.11
% Prod.	90.57	0	3.70	5.73	0		
42							
% cover	62.00	0	15.00	19.00	5.00	101%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	210.00	0	7.50	9.50	13.70	340.70	124.57
% Prod.	90.99	0	2.20	2.79	4.02		
75							
% cover	48.00	0	37.00	15.00	0	100%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	240.00	0	18.50	7.50	0	266.00	97.46
% Prod.	40.23	0	6.95	2.82	0		
76							
% cover	40.00	0	55.00	5.00	0	100%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	200.00	0	27.50	2.50	0	230.00	84.27
% Prod.	86.96	0	11.96	1.09	0		

TABLE 34 (continued)

SITE NO.***	PINON/ JUNIPER	CULTIVATED HAY	UPLAND BIG SAGE/ MID-ELEVATION SAGEBRUSH	BIG SAGEBRUSH SHRUBLAND (BOTTOMLAND)	MIXED MOUNTAIN SHRUBLAND	TOTALS	UNIVERSE PERCENTAGE
77							
% cover	40.00	0	47.00	13.00	0	100%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	200.00	0	23.50	6.50	0	230.00	84.27
% Prod.	86.96	0	10.22	2.83	0		
85							
% cover	28.00	0	62.00	11.00	0	101%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	140.00	0	31.00	6.50	0	177.50	65.03
% Prod.	78.87	0	17.46	3.66	0		
96							
% cover	61.00	0	8.00	25.00	0	94%*	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	305.00	0	4.00	12.50	0	321.50	117.80
% Prod.	94.87	0	1.24	3.89	0		
134							
% cover	65.00	0	10.00	25.00	0	100%	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	325.00	0	5.00	12.50	0	342.50	125.49
% Prod.	94.89	0	1.46	3.65	0		

TABLE 34 (continued)

SITE NO.	PINON/ JUNIPER	CULTIVATED HAY	UPLAND BIG SAGE/ MID-ELEVATION SAGEBRUSH	BIG SAGEBRUSH SHRUBLAND (BOTTOMLAND)	MIXED MOUNTAIN SHRUBLAND	TOTALS	UNIVERSE PERCENTAGE
5RB 271							
% cover	44.00	15.00	24.00	13.00	0	96%**	
gms/m^2/day	5.00	2.74	.50	.50	2.74		
Totals	220.00	41.10	12.00	6.50	0	279.60	102.44
% Prod.	78.68	14.70	4.29	2.32	0		
$\bar{X}$ % Prod.	82.56	1.63	6.61	3.20	.45		
High	94.89	14.70	17.46	5.73	4.02		
Low	78.68	0	1.24	1.09	0		
σ	16.95	4.90	5.57	1.27	1.34		

*5% lies beyond vegetation map boundary
**2% occupied by Square S Ranch house complex
2% lies beyond vegetation map boundary
***All site numbers are D.U. Field #'s except 5RB 271 (see Olson et al. 1975)

sage and grassland zone running second. The averages of the remaining zones are found in Table 34 (Part 2).

In terms of food productivity for human beings, the pinon/juniper is the preferred zone. For mule deer the dense stands of sage and rabbitbrush are preferred though for short periods of time the juniper berries are eagerly sought after as well. Comparison of catchment productivity in terms of consumption is contained in Table 35.

The 6.7:1 ratio of human consumables over mule deer consumables within the catchment area is a complete and total reversal of the situation in the Naval Oil Shale Reserve. It is, however, exaggerated. The 13.02 per cent of catchment productivity can only supply at best approximately forty per cent of the mule deer diet (Kufeld 1973); the remaining sixty per cent must come from the pinon/juniper zone. It is estimated that 19.53 per cent of the pinon/juniper zone will make up the balance of the mule deer's nutritional requirements. Under these circumstances the balance of human consumables to mule deer consumables is 67.45 per cent of catchment devoted to human consumption, 13.02 per cent to mule deer consumption and 19.53 per cent is overlap or joint use. Thus 67 per cent of the catchment area can be assigned to human sustenance and 33 per cent can be assigned to the mule deer--a complete reversal from

TABLE 35

COMPARISON OF CATCHMENT PRODUCTIVITY IN TERMS OF CONSUMPTION BY MAN AND MULE DEER IN THE DUCK CREEK REGION, PICEANCE BASIN, COLORADO

SITE NO.*	PERCENTAGE OF CATCHMENT PRODUCTIVITY CONSUMABLE BY HUMANS	PERCENTAGE OF CATCHMENT PRODUCTIVITY CONSUMABLE BY MULE DEER
23	90.56	9.40
42	90.99	9.01
85	78.87	21.13
96	94.87	5.13
75	90.23	9.77
76	86.96	13.04
77	86.96	13.04
134	94.89	5.11
5RB 271	68.43	31.57
	$\bar{X}$ = 86.97	$\bar{X}$ = 13.02

*D.U. field numbers except 5RB 271 (see Olson et al. 1975) the situation that prevails in the Naval Oil Shale Reserve.

As noted earlier the Naval Oil Shale Reserve sites were located in such a manner as to maximize access to the mule deer summering on the high plateaux of the Reserve. It would seem that the Duck Creek sites were located so as to maximize access to the nuts and berries of the pinon/juniper woodland zone. Contact, however, was still maintained with the mule deer due to joint use of the pinon/juniper zone.

One site, 5RB 271, stands out as being appreciably different. It is the only site in which approximately one-eighth of the catchment area can be considered arable land (cultivated hay).

While no diagnostic artifacts were recovered in the test excavation of this site (Grady 1976), it is the only site with Fremont rock art in the Piceance Basin. Aerial photographs also indicate the existence of possible aboriginal fields adjacent to the site. It is thought that the site represents multiple interests. Corn crops could be sown in the spring and harvested in the fall along with pinon nuts and juniper berries, and fall harvest could also include deer hunting (see Appendix H).

CHAPTER VII

THE ETHNOGRAPHIC RECORD

The environmental model developed in Chapter IV and tested in Chapter VI also needs to be tested against the archaeological and ethnographic records. In other words one would expect to have a reasonable degree of agreement between the artifact inventory as it applies to subsistence activities and the environmental model's implied resource availability.

In the last chapter analysis of the site catchments produced the following general picture. In the highland Naval Oil Shale Reserve sites selected for catchment analysis exhibited a higher productivity area/index than the surrounding regional universe. Based on consumption by species, an average of 33.46 per cent of the catchment productivity is consumable by man, while 66.64 per cent is consumable by mule deer.

In the lowland Duck Creek area the situation is dramatically reversed with 86.97 per cent of the catchment consumable by man and only 13.02 per cent exclusively consumable by mule deer. Even allowing for joint use of the pinyon juniper zone, we still have a situation in which 67 per cent of the catchment can be allocated to human consumption and 33 per cent to the mule deer.

We have, then, a tested model which indicates that deer should be the prime resource in the high country and pinyon nuts and juniper berries the prime resource in the low country.

Archaeologically we would expect tools used to process meat to be in abundance in the high country and tools used to process plant foods should predominate in the low country.

The Archaeological Record

A breakdown of the artifact inventory of the 76 sites in the Naval Oil Shale Reserve and of 69 sites in the Duck Creek/Corral Gulch area is set forth in Table 36.

Major points of divergence seem to occur in three main areas. The Naval Oil Shale Reserve region has approximately twice as many sites having grinding stones as does the Duck Creek region. On the other hand the Duck Creek/Corral Gulch area leads by far in sites with scrapers and knives. A superficial interpretation of the artifact inventory, by region, would seem to indicate that because of the high percentages of sites with grinding stones that the prime activity of the high country was the grinding or pulverization of plant food and the high percentages of sites in the low country containing scrapers and knives plus the low percentage of sites with grinding stones would by the same logic

TABLE 36

ARTIFACT INVENTORY OF SELECTED SITES OF THE PICEANCE BASIN, COLORADO

ARTIFACT TYPE	NOSR AREA (%ages)	DUCK CREEK/CORRAL GULCH AREA (%ages)
Sites w/points and point fragments	34.21%	35.82%
Sites w/grinding stones	65.79%	34.33%
Sites w/both points and grinding stones	21.05%	17.91%
Sites w/chipping debris	19.74%	19.40%
Sites w/cores	14.47%	00.00%
Sites w/scrapers	7.89%	47.76%
Sites w/knives	0.00%	29.85%

be indicative of a region with an emphasis on hunting.

It would then seem at first examination that the evidence dealing with economic activities by region provided by the archaeological record is contradictory to that provided by site catchment analysis. Part of this apparent contradiction centers on the role of the various types of grinding stones recovered in both high country and low country sites.

What must be determined is to what degree were the grinding stones (i.e. manos, metates, and mauls) or any other implement designed to grind or pulverize food used to process meat as well as vegetal resources. Second, it must be determined to what degree were grinding stones, etc. used to prepare pinyon nuts particularly in the pinyon/juniper zones or were people concentrating their efforts on harvesting activities and less on immediate processing. Resolution of these questions may be attempted by consulting the ethnographic record.

The Ethnographic Record

Despite limitations imposed by short-term periods of observation, problems posed by the use of biased historical documents, frequent noncomparability of ethnographic and archaeological research, and the fact that modern Indians are behaviorally far removed from the behavior patterns of their ancestors does not negate the use of ethnographic data. Ethnographic descriptions add color and richness and flesh out details of the man/environmental relationship often lacking in the archaeological record.

Fortunately, a corpus of reliable data does exist for the Piceance Basin. Certainly, the work of Anne Smith (1974) on the Ute of Northern Colorado and the numerous studies, articles, and reports of Omer Stewart dealing with the Ute represent a trove of data of vital interest to any archaeologist working in an area of prior Ute occupation such as the Piceance Basin.

Anne Smith (1974:76) reports differences in Utah and Colorado Ute staple diet and these differences are attributed to differences in terrain and to the relative abundancy or scarcity of various species of game or plants. She then states:

> Venison was the preferred meat, and in areas where deer were abundant (Colorado and the Uintah and other valleys in Utah) it constituted a major portion of the diet (1974:46).

Hunting Techniques

Hunting techniques of the Ute peoples were varied and seemed to change by season. In cold weather hunters would hide by a deer trail at night to ambush passing animals. A common feature of the hunt was the building of a very small fire in a deep hole to keep the hunter's hands warm and supple so he could manipulate his bow. According to Smith (1974:52), if he was successful and made a kill, he left it in place and returned the next day and butchered the animal.

Late summer techniques involved blowing on a large folded leaf to imitate the cry of a fawn to lure does to within killing range (Smith 1974:52-53).

In the fall when the deer moved from summer to winter range the Ute placed piles of brush at intervals on either side of the trail converging to a point where a deep hole was dug and camouflaged with brush. When the deer fell in, he was an easy shot. Smith (1974:53) states that several deer were often taken in succession by this method. Smith also reports (1974:53) that deer were stalked on foot and, with the advent of the horse, surrounds were also attempted.

Stewart (1942) also reports Ute Indians using the surround technique and various types of ambushes and, in some cases, driving the animals past a hidden hunter. Like Smith, Stewart also describes the use of trail side pits, heat pits, piled brush along trail sides, camouflaged pits, and single hunter stalks. He too recorded the use of game calls to lure does to within killing range.

Three points clearly stand out in these forms of hunting. The first is obvious, to hunt in this manner requires an intimate and detailed knowledge of the animals' migration routes. It also requires an intimate and detailed understanding of the deer's personality and natural senses. Without this, ambush cannot be successful since the animal must be lured into a greater and greater sense of security as he gets closer to the point of intercept. Secondly, the techniques involved, except the drive, are designed to minimize the trauma of being hunted; consequently, repetitive taking of the prey is possible as noted above. Drives on the other hand involve the deliberate introduction of trauma or fear to the point that it overrides the normal caution of the animal. Control, manipulation, and administration of trauma is an essential aspect of successful cropping of animals.

The third point to be made concerns movement. In virtually all cases described the hunter positioned himself in such a manner as to permit the animal to come to him. It would seem that only urbane, civilized man goes out and "hunts" or looks for deer. Primitive man knew where the animals were and where they were moving to; consequently, he tended to let the animals come to him.

A fourth and final point to consider is one of seasonality of hunting. Smith (1974:279) reports the month of November as being viewed by the White River Ute as "start hunting deer. Leaves all fall." This fall orientation toward hunting may be reflective of the introduction of Anglo game regulations. Certainly

Kelly (1964:48) and Stewart (1977 personal communication) argue that deer were hunted all year round with Stewart claiming that deer were "hunted when easiest to hunt."

Butchering and Meat Processing Techniques

Once an animal was killed, a whole series of follow-up activities to convert it into usable food and various by-products were set in motion. First the animal was butchered and the meat was prepared and preserved.

In skinning the deer the first cut was made under the throat and down through the belly. Next the front legs were slit and then the back legs were slit. When the Utes had horses, the four legs of the deer were then tied together, the carcass was placed on its hide, and the whole package was packed back to camp for butchering. Before reaching the camp, its eyes were removed (Smith 1974:48-49).

The meat was cut into thin strips and hung up to dry:

> Drying racks varied in size and shape. Three tall poles were set up tipi fashion, and buckskin lines were tied from pole to pole and the strips of meat were hung on them. If there were a great deal of meat, three of these "tipis" might be set up and long lines or poles stretched from one to the others (Smith 1974:48).

Haunches and shoulders were usually put on hot coals for a few minutes, turned to cook the other side, then hung and dried. The deer's head was placed by the fire to roast and the brains were used in hide tanning (Smith 1974:48). Generally, the drying process took two to three days to complete, and small fires placed under the hanging meat strips helped accelerate the process.

When drying was complete, the meat was pounded on a flat stone with a pestle-like stone mano. The mano was held perpendicularly in both hands and pounded into the meat with an up-and-down motion (Smith 1974:48). The bones of the deer were pounded as well, then boiled. When the meat was pounded to the right consistency, it was placed on a piece of rawhide and the grease from the boiled bones was poured over it with a wooden ladle. The grease and meat were then mixed by hand and packed into leather bags (a rawhide bag or parfleche some twelve by eighteen inches in size) or made into balls the size of a baseball (Smith 1974:48-49). The same techniques were used on the meat of elk, bison, and antelope. Omer C. Stewart (1977, personal communication) described hammer stones being used to pound meat and he reported that choke cherries were often dried, ground up and mixed with the pulverized meat to make pemmican.

Pinyon Nuts, Harvest and Preparation

There is voluminous literature describing the role of the pinyon nut in the dietary regieme of Great Basin peoples. The seasonal use of this nut is a prominent feature of the studies of J. Steward (1938) and D. H.

Thomas (1972:73), and ethnographic descriptions of its use are found well into the last century. For example, between 1868 and 1880 John Wesley Powell recorded a series of observations bearing on the subsistence patterns of the Numa speaking peoples (m.s. 830, Fowler, D. D. and Fowler, C. S. 1971:39) in which the pinyon nut plays a prominent role.

In all the ethnographic literature pertaining to the use of the nut, certain basic facts stand out. Yields of the nuts can border on the astronomical; thus shear numbers make it a likely staple item. Second, it is highly nutritious. Third, the nut is easy to preserve either in cones or as individual nuts. Finally, it can be prepared in a number of different ways thus minimizing dietary boredom. The only real problem is the unreliability or erratic productivity of the trees. People who exploit the pinyon have to be prepared to travel, often considerable distances, to exploit highly productive trees.

Interest in this study is much narrower in that we are trying to determine to what degree grinding stones were used to grind pinyon nuts in areas where site catchment analysis tells us pinyon nuts are the prime resource.

Powell reports (D. D. Fowler and C. S. Fowler 1971: 39) that the cones containing pinyon nuts are gathered in the fall before the nuts are ripe and have a chance to fall to the ground. The gathered cones are thrown into a fire where the cones are charred and the nuts partially roasted. The nuts are then separated from the chaff by picking out with the fingers. Powell then notes the nuts receive no further preparation. Seasons when the nuts are particularly abundant, great stores of them are laid away for winter. Some nuts will be further roasted slowly and thoroughly and then ground into a meal.

Kelly (1964:43) also reports that dried pine nuts, unhulled, were stored in buckskin bags for winter. She also reports the making of mush out of the nuts.

Smith (1974) reports that in years when pine nuts or pinyon nuts were plentiful, several families would gather together and camp near the pinyon groves. Again the pattern was to collect the cones which were beaten to shake loose the nuts. The nuts might be stored as is or placed in a basket with hot coals and shaken until the shells popped off.

The other anomaly in the archaeological record, the presence of large numbers of sites with scrapers and knives, may best be explained by fall hide or fur processing activities.

Rabbit skin blankets used as robes and bedding are reported from throughout the Ute/Southern Piaute area

(Smith 1974; Kelley 1964). Smith in describing the Colorado Ute reports blankets made of skins of hares and rabbits were used in cold weather by men, women, and children (1974:69-71). Fur blankets and robes were not limited to rabbit and hare. One informant noted: "Any kind of animal that had fur, they would catch it and tan and sew the skins together with sinew and make robes out of them. Anything at all that was furry and would keep them warm" (Smith 1974:71-72). Animals specifically listed include badger, woodchuck, coyote, and gray wolf. Smith (1974:77) also noted that the Colorado Utes usually had blankets made of buffalo hide tanned on one side. Other animals were used as well, but buffalo was preferred.

There is no direct ethnographic evidence to support the idea that fur and hide and blanket preparation was a fall activity but this is the ideal time since fur-bearing animals' coats are at their best. The imminent onset of winter would certainly be incentive enough to refurbish the winter wardrobe. With a harvest of 24,813 cottontail rabbits in 1968 and another 11,606 in 1969 from game management unit 22, which corresponds roughly to the low elevation portion of the Piceance Basin, it would seem there are enough fur-bearing animals available for exploitation (Baker and McKean 1971:38).

The apparent contradiction described earlier between the environmental model and the archaeological record does not seem to hold up when compared with the ethnographic record. It would seem that the presence of comparatively large numbers of sites with grinding stones is entirely consistent with meat processing activities plus processing the rich vegetal component present in the short growing season in the high country. On the other hand the presence of comparatively few sites with grinding stones, coupled with large numbers of sites with both knives and scrapers in the lowland areas is entirely consistent for an area whose prime resource is its storable nut crop and its comparative abundance of fur-bearing animals.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

In the closing pages of the first chapter of this paper, four specific goals were set out for study. The specific goals were:

1. to identify those environmental factors which impinge upon site location decisions;
2. to determine to what degree the impact of these factors varies by defined region;
3. to locate within these defined regions those areas characterized by high site density and those areas characterized by low site density and to be able to comment on the probable cause of this inequitable distribution;
4. to integrate these geographically diverse regions into a cohesive whole, the development of a descriptive model of economic behavior.

Achievement of these goals required the formulation of a series of four rather general hypotheses drawn from an environmental model. These general hypotheses are set out below:

> Site location in the Piceance Basin is a function of and is reflective of societal structure.

> Physiography exerts a major impact on site location in the Piceance Basin.
>
> The nature and distribution of vegetation is a major factor influencing site location in the Piceance Basin.
>
> The seasonal movement of the basin's herd of mule deer exerts major influences on site location decisions.

Only the first of these hypotheses can be directly tested and point pattern analysis indicated that the highland sites in the Naval Oil Shale Reserve tend to cluster and the cluster effect is more pronounced in the northern portion of the Reserve, exhibiting a preference for broad flat valleys. Steep, precipitous valleys unsuited for occupation characterize the southern portion of the Reserve where sites tend to be found on upland feeder streams and are thus more randomly distributed.

In the lowland Duck Creek region sites are clustered but only just, the departure from randomness being quite minimal. The tendency toward randomness in the lowlands may reflect the need to scatter over the landscape to more effectively exploit plant resources while the highland tendency to cluster may reflect a desire to minimize disturbance of the mule deer herd.

Testing of the specific hypotheses drawn from the rest of the general hypotheses produced the following results.

Distance to Water as a Factor

H_O 1: If the distance to water exerts no influence on archaeological site location decisions, then as distance to water increases there should be no significant change in archaeological site frequency.

H_A 1: If the distance to water exerts an influence on archaeological site location decisions, then as distance to water increases archaeological site frequency should decrease.

In both the Naval Oil Shale Reserve and Duck Creek/ Corral Gulch area the null hypothesis is rejected and the alternate hypothesis accepted. However, the effect of distance to water is more pronounced in the Naval Oil Shale Reserve.

Topography as a Factor

H_O 2: If slope is not a factor in influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of slopes present in the region.

H_A 2: If slope is a factor influencing archaeological site location decisions, then archaeological sites should be found within a clearly defined range of slope angles.

In both test areas descriptive statistics indicate a preference for certain slopes with no sites being found on a slope of over 20 degrees. Consequently, it is felt that the null hypothesis is rejected and the alternate hypothesis accepted.

H_O 3: If aspect is not a factor influencing archaeological site location decisions, then archaeological sites should be evenly distributed throughout the range of headings present in the region.

H_A 3: If aspect is a factor influencing archaeological site location decisions, then archaeological sites should exhibit a marked preference for certain headings and an avoidance of others.

Again, the null hypothesis is rejected for both test areas and the alternate hypothesis accepted.

Soils as a Critical Factor in Site Location

H_O 4: If the distribution of soils exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the landscape in a manner proportional to soil zone coverage.

H_A 4: If the distribution of soils exerts a marked influence upon archaeological site location decisions, then archaeological sites will be distributed non-randomly with regard to soil zone coverage.

In both test areas the null hypothesis is accepted and soils are eliminated as a factor effecting site location.

Vegetation as a Factor Affecting Site Location

H_O 5: If the distribution of vegetation exerts no influence upon archaeological site location decisions, then archaeological sites will be distributed over the landscape in a manner proportional to the vegetational zone coverage.

H_A 5: If the distribution of vegetation exerts a marked effect upon site location, then archaeological sites will be distributed non-randomly with regard to vegetational zone coverage.

In both the Naval Oil Shale Reserve and Duck Creek areas the null hypothesis is again rejected and the alternate hypothesis is sustained.

H_O 6: If there is no significant similarity in the food preferences of man and the mule deer, then there should be little or no correlation between the foods consumed by both species.

H_A 6: If there is a significant similarity in the food preferences of man and the mule deer, then there should be a marked correlation between the foods consumed by both species.

Testing of this hypothesis results in the rejection of the null hypothesis and acceptance of the alternate hypothesis.

Testing of various characteristics of vegetation produces the following results:

H_O 7: If variety as defined above exerts no influence upon archaeological site location decisions, then an increase in variety will not produce an increase in archaeological site frequency.

H_A 7: If variety as defined above exerts an influence on archaeological site location decisions, then an increase in variety should result in an increase in archaeological site frequency.

In the Naval Oil Shale Reserve there is a low negative correlation, -0.10, and a significance score that indicates that the correlation could occur by chance. Consequently the null hypothesis is accepted. The opposite is true for the Duck Creek area. Here the correlation is -0.90 and is significant at the .05 level, indicating a situation contrary to either hypothesis. Instead we have a situation in which the number of archaeological sites tend to decrease as variety increases.

H_O 8: If density as defined above exerts no influence on archaeological site location decisions, then an increase in density will not produce an increase in archaeological site frequency.

H_A 8: If density as previously defined exerts an influence on site location decisions, then an increase in density should result in an increase in site frequency.

In both areas correlations are achieved. In the Naval Oil Shale Reserve a correlation of -0.60 makes sense since people do not live in thickets, and density of shrub zones at high altitude can result in impenetrable vegetation stands. On the other hand in the Duck Creek area the densest stands are the pinyon/juniper stands which are easily penetrable by man. Consequently a correlation of +0.30 is acceptable. However, calculated z scores indicate that the correlation of both areas could be due to chance.

H_O 9: If productivity as previously defined exerts no influence on site location decisions, then an increase in productivity will not produce an increase in site frequency.

H_A 9: If productivity as previously defined exerts an influence upon site location decisions, then an increase in productivity should result in an increase in site frequency.

In neither area is the null hypothesis rejected. Although correlations are achieved, it is felt that they are too low and that chance plays too great a role.

Computation of a productive area index and retesting of the last hypothesis did produce a convincing correlation of +0.90 between site location and productivity in the Duck Creek region, but a value of +0.10 for the Naval Oil Shale Reserve is not convincing.

The final hypothesis deals with a comparison between the site's catchment area and the surrounding universe.

H_O 10: If there is no significant difference between the observed percentages of vegetational zones contained within the catchment area and that of the regional universe, then the catchment will exhibit the same vegetational characteristics as the regional universe.

H_A 10: If there is significant difference between the observed percentage of vegetation zones contained within the catchment area and that of the regional universe, then the catchment will exhibit different vegetational characteristics than that of the regional universe.

All sites chosen for catchment analysis in the Naval Oil Shale Reserve and all, but one, in the Duck Creek area were significantly different than their surrounding universes, thus rejecting the null hypothesis eighteen out of nineteen times.

Productivity as a factor emerges for the Naval Oil Shale Reserve when catchments are evaluated in terms of consumability. In the highland areas the two most productive areas, Douglas fir and aspen, have no archaeological sites, but between them they provide on the average 66 per cent of the total catchment productivity. It is from these zones that the mule deer derive the bulk of their food.

Application of the results of the hypothesis testing to the study area permits the following observations. Within the Naval Oil Shale Reserve portion of the

Piceance Basin water seems to have been the prime locational determinant with vegetation ranking second. Slope and aspect were also factors influencing locational decisions, but these considerations ranked a distant third. Soil type seems to have had no influence or impact whatsoever. If we couple the effect of distance to water (100 meters) and type of vegetation, deleting the Douglas fir and aspen community and the shrub communities, and slopes over 20 degrees, we find that 10.88 per cent of the landscape will produce 89.29 per cent of the total site inventory in the Naval Oil Shale Reserve.

The situation in the Duck Creek/Corral Gulch portion of the Basin is different. Here the distribution of vegetation, particularly the pinon/juniper zone, is the prime mover in locational decisions. Distance to water is also a factor but not nearly to the degree found in the Naval Oil Shale Reserve. Slope angle and aspect are also factors affecting the location of archaeological sites. In fact the effect of slope orientation is stunning in that 81 per cent of the total site inventory is found on slopes with headings between 340 degrees and 160 degrees, a span of 180 degrees. Part of this phenomenon is undoubtedly due to the general northeast tending downward of the Basin, and part is due to the desire of peoples in the Basin to settle on the lee side of hills and thus minimize the effect of the winter storm track. Certainly the desire to avoid the winter storm track accounts for the total avoidance of southwest facing slopes. As in the Naval Oil Shale Reserve, soils do not seem to be a significant factor in influencing site location.

In contrast to the Naval Oil Shale Reserve portion of the Basin elimination of factors that do not seem to be conducive to site location, i.e., distance to water (1,000 meters), slopes over 15 degrees, and alluvial valley bottoms, produces a situation in which 14.91 per cent of the landscape is potentially devoid of archaeological sites. In other words 85.11 per cent of the landscape produces 100 per cent of the site inventory in the Duck Creek/Corral Gulch portion of the Piceance Basin.

Delineation of those factors that influence site location by region does, of course, closely approximate Willey and Phillips' (1958) descriptive level. The development of a scheme that not only explains where but why approximates Willey and Phillips' (1968) explanatory level. This need of explanation led to the use of the catchment technique and the evaluation of the resources contained therein.

Catchment evaluation of sites in the Naval Oil Shale Reserve indicates that sites have a higher productivity index than does the basic universe and that the catchments exhibit close to a two-to-one preference for mule deer forage. In other words sites found within the

Naval Oil Shale Reserve are situated in such a manner as to maximize access to the Piceance Basin herd of mule deer on their summer range.

In the low elevation Duck Creek/Corral Gulch region the situation is virtually reversed. In this area catchment analysis reveals that foodstuffs suitable for human consumption exceed by far those of the mule deer. Even allowing for joint use of the pinon/juniper zone by both man and mule deer, 67 per cent of the catchment area can still be assigned to human sustenance and the remaining 33 per cent to the mule deer.

Considering the divergent nature of the catchment by region it would seem that the intensity of resource exploitation varies by season. Using the mule deer as an example, we can see that summer is the time of the most intense man/animal contact and early spring the time of least contact. Winter has taken its toll in death and weight loss and the animals are widely dispersed to maximize what little nutrition is available. Man is in the position of having to expend more calories in hunting the animal than the animal can return. The rest of the year is probably a maintenance situation in which deer are cropped as needed. Only in the summer does this situation change when large numbers of animals are concentrated in comparatively small areas, making intense exploitation an economically viable activity. By this time of year the meat is in much better condition.

Summertime is the optimum time to take large numbers of animals, butcher them, dry and pound the meat into powder, mix it with fat, pack it into parfleches, and store it for late winter and early spring consumption. Early fall blizzards and heavy snows that severely restrict movement tend to make any delay in the acquisition of these winter rations a high-risk strategy. Summer in the high country is the optimum time for man to prepare those rations needed to survive the long hard winters of Western Colorado.

In those periods when mule deer exploitation was intense, vegetal resource exploitation seems to have had a low priority and even when the vegetal resources were being intensively exploited, man still maintained contact with the mule deer. At no season in the year did man seem to be totally out of contact with the deer. This synchronization of man's movements to match those of the mule deer produced a system of overlapping behavioral patterns that varied by season. What prehistoric man in the Piceance Basin appears to have established was a relationship with the mule deer that ranges from parasitism at one extreme to casual cropping at the other.

If, as the catchment analysis seems to imply, settlement pattern varies with the resource being exploited, then the very nature of a given pattern of settlement could be diagnostic. Randomly distributed sites seem primarily devoted to the exploitation of plant resources, while highly clustered distributions are indicative of animal exploitation. In other words the nature of the settlement pattern is reflective of economic activities of man within the Basin. To what degree this might hold true outside the Basin has yet to be determined.

The decisions of where to locate occurs on two different levels. The first level involves basic economic decisions and the second is adjusted to personal preference and convenience. The first level of decision-making asks questions dealing with what and where is the most profitable resource for exploitation at any given time of the year, and how can the most be made of it. Decisions at this level tend to be rational, economic decisions.

The second level answers questions dealing with such choices as nearness to water, closeness to neighbors, and hillside or slope preferences. These questions try to answer why area A is preferable to area B. This is the idiosyncratic level and questions posed at this level can only be answered after the basic economic decisions have been reached.

It is possible to reconstruct an annual cycle of economic activity for the Piceance Basin. We know, for example, that early spring is the time of greatest hardship in the annual economic cycle. At this time of the year food reserves prepared for the winter are exhausted and new foods are not yet available. The Ute refer to this season as the "strips of buckskin" season (Smith 1974:278) referring to that time of the year when only the leather bags that once contained the winter rations are left to be consumed.

Lowland marshes adjacent to the main drainages of the White River contain the first foods available for human consumption in the spring. It is here that the starch-rich rhizomes and corms of the rush, cattail, and reed are found. Once spring has set in there is a short but intense burst of new growth suitable for consumption but when this initial burst of productivity is over, the lowlands are comparatively unproductive until fall.

High elevations, over 8000 feet above sea level, are the centers of high consumable productivity during the summer. Here the short growing season produces an unexpected lushness of foods attractive to man and animals as well. As noted earlier in the chapter, this is the time to hunt deer and to prepare food reserves for winter.

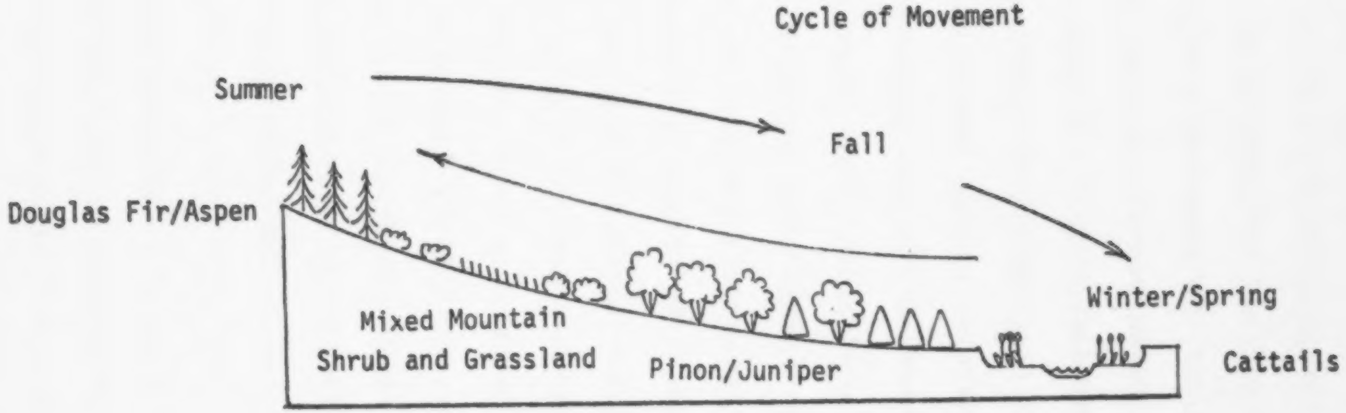
High country snows at the end of the season finally force both humans and animals to seek food and shelter in the lower elevations of the Basin (between 8000 and 6000 feet above sea level) where new crops, particularly pinon nuts and juniper berries are coming into season. The final move of the season occurs when man moves into the sheltered valleys for the winter. This pattern of complementary resource exploitation and seasonal movement seems to have had a long antiquity in the basin which survived into the historic period (see Fig. 20).

Key archaeological problems of the Piceance Basin seem to focus on the Fremont/Archaic interface. West and immediately adjacent to the Basin in Douglas Creek a series of sites have been recovered, reported on, and attributed to the Fremont Culture (Wenger 1956, Jennings 1974, 1976, and Hurlbutt 1976). It is characterized by dry-laid masonry cists, calcite tempered pottery, hand-sized grinding stones, and rock paintings with trapazoidal, horned figures. Like all areas of Fremont affiliation the Douglas Creek area is also thought to have supported maize horticulture. Wenger also notes (Wormington 1955:142) the similarity in both masonry styles and calcite tempered pottery of the Douglas Creek area and the Castle Park area of Dinosaur National Monument. Marwitt (1971) would include both areas within his "Uinta" Fremont sub-area.

As late as 1974 C. Jennings argued that evidence for Fremont occupation of the Piceance Basin was slight. He noted (1974:28), "It seems advisable to argue that there was no permanent occupation of the Basin during the time they were present in even nearby areas such as Douglas Creek." While he is willing to concede the possibility of Fremont peoples coming into the Basin in search of game and vegetable products, Jennings still

FIGURE 20

RECONSTRUCTION OF HISTORIC UTE/ARCHAIC ANNUAL ECONOMIC CYCLE


Cycle of Movement
Summer
Fall
Winter/Spring
Douglas Fir/Aspen
Mixed Mountain
Shrub and Grassland
Pinon/Juniper
Cattails

feels that the cultural affiliation of the Basin is not Fremont but "Archaic."

Archaic as used by Jennings follows the classic definitions of J. D. Jennings (1957, 1964, and 1974) which stress intensive utilization of a wide variety of resources, and exploitation of these resources based on a cycle of seasonal movement. Obviously, this requires extensive knowledge of the seasonal availability and utility of plants and an intimate knowledge of the behavior patterns of animals. Very little was overlooked as a potential food source during the Archaic period. Population was usually sparse with small groupings of people. The necessity of remaining mobile produced an artifact inventory that was lightweight and portable. Netting, basketry, varieties of sandals, grinding stones, dart points, decoys all point to a technology that was finely adapted to a harsh environment. The Archaic lifestyle represents a form of environmental adaptation whose artifactual inventory varies with the resource or the environmental region being exploited.

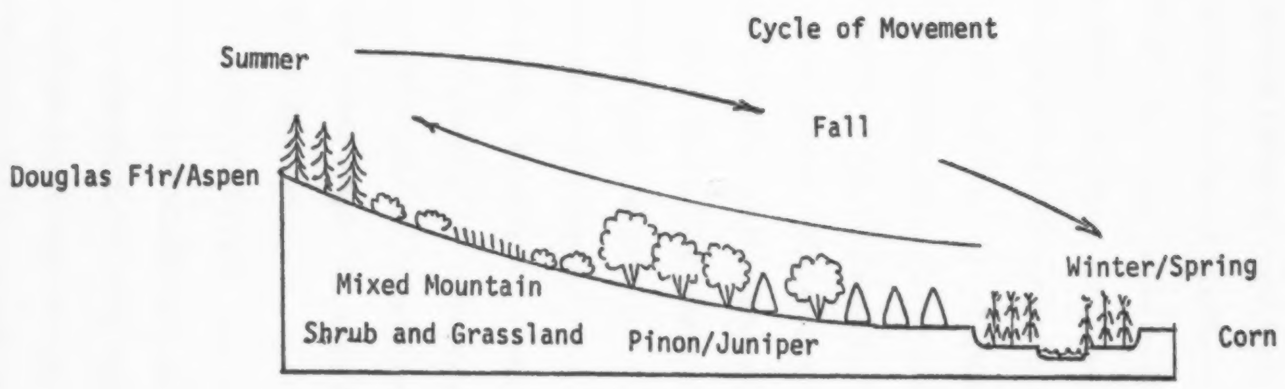
Is there a cultural boundary between the Fremont and Archaic cultures as C. Jennings (1974) argues? If so, is there cultural interchange between the two? Or is it possible that the "boundary" does not exist? The recovery of site 5RB 271 with its trapazoidal rock art, grinding stones, and possible presence of aboriginal fields on the flood plain of Piceance Creek interjects evidence of Fremont culture within the Basin. We are left with a picture in which we have an island of Archaic culture surrounded by Fremont culture. It is interesting to note that the Fremont culture seems to be a lowland phenomenon being found in or adjacent to the valleys of the Basin. Under these circumstances we may be faced with a situation in which lowland activities tend to be referred to as "Fremont" while the highland activities of the same group are referred to as "Archaic."

If the Fremont and Archaic lifestyles are in reality nothing more than differing sets of economic activities employed by the same people but at different times of the year, it should be possible to reconstruct a cycle of annual economic activities that account for the Fremont element within and adjacent to the Basin. In fact the Ute highland/lowland dichotomy lends itself to such a reconstruction. In this case spring planting of corn can be added to the lowland/spring quest for food, followed by the highland/summer deer harvest. Fall would find the Fremont peoples harvesting pinon nuts. Final movement into the valleys would permit harvest of the corn sown in the spring (see Fig. 21).

If, as Breternitz argues (1970:163), the Fremont culture came to an end somewhere around 1200 A.D., it does not necessarily mean that Fremont peoples abandoned

FIGURE 21

RECONSTRUCTION OF PROBABLE FREMONT ANNUAL ECONOMIC CYCLE


Cycle of Movement
Summer
Fall
Winter/Spring
Douglas Fir/Aspen
Mixed Mountain
Shrub and Grassland
Pinon/Juniper
Corn

Northwest Colorado to be replaced by new peoples. Clark (1965) has argued against the tendency of archaeologists to invoke migrations as explanatory mechanisms to account for change of artifact styles within a region.

In the Piceance Basin the change from Fremont culture to some sort of prehistoric Ute culture may be nothing more than the dropping of an unprofitable economic activity (growing and storing of corn) due to deteriorating climatic conditions and a redirection of one's economic activities into more profitable channels. Such a shift to a more profitable economic activity certainly occurred when the Ute acquired the horse and started to pursue a lifestyle reminiscent of the plains Indians. Retention of certain profitable seasonal economic activities would tend to account for the long duration (some 8776 years) of C. Jennings' (1974) "Archaic Period" life style and the long term persistence of the artifact style associated with it.

It is interesting to note to what degree the modern environment can be used to produce rational, plausible or coherent explanations dealing with the distribution of archaeological sites. Techniques such as site catchment analysis provide a method by which archaeological sites and their artifact inventories may be related to specific factors within their environmental setting and thus permit reconstruction and evaluation of a site's economic function. The fact that this environmental data base can be derived from aerial photography permits evaluation of a site's setting long after the landscape has been modified by man's modern industrial needs.

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APPENDIX A

VASCULAR PLANTS OF THE PICEANCE BASIN COLORADO

Sources

Plant presence in Basin:

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Ward, et al. 1974
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Rio Blanco Oil Shale Project 1974

Plant presence in Northwestern Colorado:

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Weber, W. A. 1972

Plants suitable for human consumption in the Piceance Basin, Colorado:

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Plants suitable for mule deer consumption in the Piceance Basin, Colorado:

Kufeld, et al. 1973

APPENDIX A

VASCULAR PLANTS OF THE PICEANCE BASIN

TREE LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Acer negundo L. var. interius (Britt.) Sarg.	Box Elder	N	X	X
Juglans nigra L.	Black Walnut	E	X	
Juniperus osteosperma (Torr.) Little.	Utah Juniper	N	X	X
Morus rubra L.	Red Mulberry	E	X	
Pinus edulis Engelm.	Pinon Pine	N	X	X
Populus augustifolia James	Narrow-leaf Cottonwood	N	X	X
Populus sargentii Dode.	Broad-leaf Cottonwood	N	X	X
Populus tremuloides Michx.	Aspen	N	X	X
Prunus virginiana L.	Chokecherry	N	X	X
Pseudotsuga menziesii (Mirb.) Franco	Douglas Fir	N		X
Quercus gambelii Nutt.	Gambel's Oak	N	X	X
Svida sericea (L.) Holub	Red-Osier Dogwood, Squawbush, Kinnikinnik, American Dogwood	N		X
Ulmus americana L.	American Elm	E		
Ulmus pumila L.	Siberian Elm	E		

SHRUB LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Acer glabrum Torr.	Mountain Maple	N	X	X
Amelanchier alnifolia Nutt.	Juneberry (Serviceberry)	N	X	X
Amelanchier pumila Nutt. ex. T. & G.	Serviceberry	N	X	X
Amelanchier utahensis Koehne	Utah Shadbush	N		X
Artemisia frigida Willd.	Mountain Sage (Fringed Sagewort)	N	X	X
Artemisia trindentata Nutt.	Big Sagebrush	N	X	X
Atriplex canescans (Pursh) Nutt.	Four-winged Saltbush	N	X	X
Atriplex confertifolia (Torr. et Fremont) S. Wats.	Saltbush	N	X	X
Atriplex nuttallii S. Wats.	Saltbush	N	X	X
Baccharis salicina T. et G.	Groundsel Bush	N		
Betula fontinalis Sarg.	River Birch	N		X
Ceanothus fendleri A. Gray	New Jersey Tea	N		X
Ceanothus velutinus Douglas ex. Hook	Mountain Laurel Snowbush, Dedbush, Tobacco Brush, Sticky Laurel, Soapbloom	N		X
Cercocarpus montanus Raf.	Mountain Mahogany	N		X
Chrysothamnus nauseosus (Pal.) Britt. in Britt. et Brown	Rubber Rabbitbrush	N		X

SHRUB LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Chrysothamnus viscidiflorus (Hock.) Nutt.	Rabbitbrush	N	X	X
Clematis ligusticifolia Nutt. et T. et G.	Western Virgin's Bower	N	X	
Clematis pseudoalpina (Kuntze) Nelson	Rocky Mountain Clematis	N		
Ephedra viridis Coville	Joint Fir	N	X	X
Eriogonus corymbosum Benth.	Umbrella Plant	N	X	
Eurotia lanata (Pursh) Moq.	Winterfat (White Sage)	N		X
Holodiscus dumosus (Nutt.) Heller	Ocean-Spray, Rock Spirea, Mountain Spray, Creambush	N		X
Holodiscus microphyllus Rybd.	Mountain Spray	N		X
Humulus lupulus L.	Hops	N	X	
Juniperus osteosperma Sarg.	Rocky Mountain Juniper, Red Cedar	N	X	X
Pachystima myrsinites (Pursh) Raf.	Mountain Lover	N		X
Parthenocissus vitacea (Knerr) Hitchc.	Virginia Creeper	N		
Prunus sp. (probably *P. melanocarpa* (A. Nels) Rydb.)	Chokecherry (Western)	N	X	X
Prunus virginiana L	Chokecherry	N	X	X
Purshia tridentata (Pursh) DC.	Bitterbush	N		X

SHRUB LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Quercus gambelii Nutt.	Gambel's Oak Juneberry Mt. Mahogany	N	X	X
Rhus sp. (Prob. R. glabra L.)	Sumac	N	X	X
Rhus trilobata Nutt. ex. T. et G.	Skunkbush	N	X	X
Ribes aureum Pursh	Golden Currant	N	X	X
Ribes cereum Dougl.	Wax Currant	N	X	X
Ribes inerme Rydb.	Gooseberry	N	X	X
Ribes viscosissimum Pursh	Sticky Currant	N	X	X
Rosa woodsii Lindl.	Rose	N	X	X
Rubus idaeus L.	Wild Red Raspberry	N	X	X
Salix exigua Nutt.	Gray Sand Bar Willow	N		X
Salix interior Rowlee	Sand Bar Willow	N	X	X
Sarcobatus vermiculatus (Hook.) Torr.	Greasewood	N	X	
Shepherdia argentea (Pursh) Nutt.	Buffaloberry	N	X	X
Svida sericea (L.) Holub.	Red-Osier Dogwood	N		
Symphoricarpos oreophilus A. Gray.	Snowberry	N		X
Tamarix pentandra Pall.	Tamarisk	E		
Tetradymia canescens DC.	Horsebrush	N		X
Tetradymia spinosa H. et A.	Horsebrush	N		
Toxicodendron radicans (L.) Kuntze	Poison Ivy	N		

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Achillea lanulosa Nutt.	Yarrow	N		
Actaea rura (Ait.)	Baneberry	N		
Aegilops cylindrica Host.	Goat-Grass	E		
Agastache foeniculum Kuntze	Giant Hyssop	N		
Agastache urticifolia Kuntze	Giant Hyssop Horse Mint	N		X
Agoseris aurantiaca (Hook.) Greene	False Dandelion	N		
Agoseris glauca (Pursh) Raf.	False Dandelion Goat Chicory Mountain Dandelion	N		X
Agropyron cristatum (L.) Gaertn.	Crested Wheatgrass	N	X	X
Agropyron desertorum (Fisch.) Schult.	Crested Wheatgrass	E	X	
Agropyron elongatum (Host.) Beauv.	Tall Wheatgrass	E	X	
Agropyron repens (L.) Beauv.	Quack-Grass	E	X	
Agropyron smithii Rydb.	Western Wheatgrass	N	X	X
Agropyron spicatum (Pursh) Scribn. et Smith	Bluebunch Wheatgrass	N	X	X
Agropyron trachycaulum (Link) Malte.	Slender Wheatgrass	N	X	
Agrostis gigantea Roth.	Red Top	N	X	X
Allium acuminatum Hook.	Wild Onion	N	X	X
Allium textile Nels. et Macbr.	Wild Onion	N	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Amaranthus graecizans L.	Pigweed	E	X	X
Amaranthus retroflexus L.	Pigweed	N	X	X
Ambrosia elatior L.	Ragweed	N		
Androsace septentrionalis L.	Fairy Candelabra	N		X
Angelica ampla A. Nels.	Angelica	N	X	
Antennaria alpina (L.) Gaertn.	Everlasting, Pussytoes	N		
Antennaria parvifolia Nutt.	Pussytoes	N	X	X
Antennaria pulcherrima (Hook.) Greene	Everlasting, Pussytoes	N		
Apocynum sibiricum Jacq.	Dogbane	E		
Aquilegia caerulea James	Blue Columbine, Colorado Blue Columbine	N		X
Aquilegia micrantha Eastw.	Columbine	N		X
Arabis drummondi A. Gray	Rock Cress	N		X
Arabis holboellii Hornem.	Rock Cress	N		
Arceuthobium douglasii Engelm.	Mistletoe	N		
Arctium minus (Hill) Bernh.	Burdock	N	X	
Arctostaphylos patula Greene, Pitt.	Greenleaf Mansanita	N		
Arenaria eastwoodiae Rydb.	Sandwort	N		

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Arenaria Sp. Two possibilities: *A. Fendleri* A. Gray *A. Congesta* Nutt. Ex. T & G	Sandwort	N		X
Arnica cordifolia (Hook.)	Arnica, Hearthleaf, Leopard's Bane	N		X
Artemisia dracunculus L.	Green Sage	N	X	X
Artemisia frigida Willd.	Pasture Sagebrush	N	X	X
Artemisia ludoviciana Nutt.	Sagebrush	N	X	X
Asclepias asperula (Dcne) Woodson.	Creeping Milkweed	N		
Asclepias cryptoceras S. Wats.	Milkweed	N		
Asclepias speciosa Torr.	Showy Milkweed	N	X	
Asclepias subverticillata (Gray) Vail	Whorled Milkweed	N		
Asparagus officinalis L.	Asparagus	E	X	
Aster foliaceus Lindl. in DC	Leafy Aster	N	X	X
Aster foliargus L. (see *A. Foliaceus*)	Michaelmas Daisy	N		
Aster glaucodes Blake	Aster	N	X	
Aster leavis L.	Smooth Blue Aster	N	X	
Astragalus canadensis L.	Canada Milkvetch	N		
Astragalus lutosus M. E. Jones	Milkvetch	N		

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Astragalus miser Dougl., ex Hook. var. oblong. folius (Rybd) Cronquist.	Locoweed Milkvetch	N		
Atriplex rosea L.	Saltbush, Orache	N	X	X
Avena fatua L.	Wild Oats	E	X	
Balsamorhiza sagittata (Pursh) Nutt.	Balsam Root	N & E	X	X
Bilderdykia convolvulus (L.) Dum.	Black Bindweed	E		
Bouteloua gracils (H.B.K.) Lag. ex steud.	Blue Grama	N		
Brickellia grandiflora (Hook.) Nutt.	Brickellbrush	N		X
Bromus ciliatus L.	Franged Brome	N		X
Bromus inermis Leyss	Smooth Brome	E		X
Bromus japonicus Thunb.	Japanese Brome	E		
Bromus marginatus Nees.	Mountain Brome	N		
Bromus tectorum L.	Cheat Grass	E		X
Calochortus nuttallii Torr.	Mariposa Lily	N	X	X
Camelina microcarpa Andrz.	False Flax	E		
Capsella bursa-pastoris (L.) Medic.	Shepherd's Purse	E	X	X
Cardaria draba (L.) Desv.	Whiteweed	E		
Carex deweyana Schwein	Sedge	N	X	
Carex geyeri Boott. (Boott.)	Sedge	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Carex occidentalis L.H. Barly	Sedge	N		
Carex rossii Boott.	Sedge	N		
Castilleja chromosa A. Nels.	Indian Paint Brush	N		
Castilleja linariaefolia Benth. in DC.	Wyoming Paintbrush	N	X	X
Ceratocephalus testiculatus (Crantz) Roth.	Crowfoot	E		
Chaenactis sp.	Dusty Maiden False Yarrow	N		X
Chamaesyce fendleri (T. et G.) Small	Spurge	E		
Chenopodium album L.	Lamb's Quarter	E	X	X
Chenopodium fremontii S. Wats.	Pigweed, Lamb's Quarter, Goosefoot	N	X	X
Chenopodium hybridum L.	Maple-leaved Goosefoot	E		
Chorispora tenella DC.	Blue Mustard, Purple Weed	E		
Cicuta douglasii (DC) C. et R.	Water Hemlock	N		
Cichorium intybus L.	Chicory	E	X	
Cirsium arvense (L.) Scop.	Canada Thistle	E	X	X
Cirsium sp.	Thistle, Golden Aster, Golden Eye	200 species in N.A. 50 are native and about 20 occur in Rocky Mt. W.		X
Cirsium undulatum (Nutt.) Spreng.	Wavy-leaved Thistle	N	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Cirsium vulgare (Savi) Tenore.	Bull Thistle	E	X	
Clematis hirsutissima Pursh.	Virgin's Bower	N		X
Clematis ligusticifolia Nutt. ex. T. & G.	White Virgin's Bower	N		X
Cleome serrulata Pursh.	Rocky Mountain Bee Plant	N	X	
Collinsia parviflora Lindl.	Baby Blue Eyes, Blue-Eyed Mary	N		X
Collomia linearis Nutt.	Collomia, Tiny Trumpet	N		X
Comandra umbellata (L.) Nutt.	Bastard Toadflax	N		X
Convolvulus arvensis L.	Field Bindweed	E		X
Conyza canadensis (L.) Cronquist	Horseweed	N		X
Corallorhiza maculata Raf.	Spotted Coral Root	N		
Corydalis aurea Willd.	Golden Smoke	N		
Crepis acuminata Nutt.	Hawk's Beard	N		X
Crepis intermedia A. Gray	Hawk's Beard	N		X
Crepis modocensis Greene S. Wats.	Hawk's Beard	N		X
Cryptantha spp.	Several species seen in study area, identification is uncertain	N		X
Cymopterus longipes S. Wats.	Cymopterus	N	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Cymopterus purpureus S. Wats.	Cymopterus	N	X	X
Cynoglossum officinale L.	Hound's Tongue	E		X
Cyperus sp.	Flat Sedge	N	X	X
Dactylis glomerata L.	Orchard Grass	E		
Delphinium nelsonii Greene	Larkspur	N		X
Descurainia pinnata (Walt.)	Tansy Mustard	N	X	X
Descurainia richardsonii (Sweet) O.E. Schulz	Western Tansy, Mustard	N	X	X
Disporum trachycarpum (S. Wats.) Benth. et Hook.	Fairy Bells	N		
Distichlis stricta (Torr.) Rydb.	Desert Saltgrass	N		
Draba reptans (Lam.) Fernald	Whitlowgrass	N		X
Echinocereus triglochidiatus Engelm. Var. Melanacanthus (Engelm.) L. Benson	Hedgehog Cactus	N	X	
Echinochloa crus-galli (L.) Beauv.	Barnyard Grass	E	X	
Eleocharis macrostachya Britt.	Spice Rush	N		
Elymus canadensis L.	Canada Wild Rye	N	X	
Elymus cinereus Scribn. et Merr.	Giant Wild Rye	N		X
Epilobium adenocaulon Hausskn.	Fireweed	N	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Epilobium brevistylum Barbey.	Willowherb	N	X	X
Equisetum arvense L.	Field Horsetail	N	X	X
Equisetum variegatum Schleich.	Variegated Scouring Rush	N	X	X
Erigeron sp.	Fleabane	N		X
Erigeron caespitosus Nutt.	Daisy Fleabane	N		X
Erigeron formosissimus Greene	Fleabane, Daisy	N		X
Erigeron lanatus Hooker	Fleabane, Daisy	N		
Erigeron subtriervis Rydb.	Daisy Fleabane	N		
Erigeron utahensis A. Gray	Daisy Fleabane	N		
Eriogonum alatum Torr.	Tall Yellow Eriogonum, Winged Buckwheat	N		X
Eriogonum caespitosum Nutt.	Eriogonum	N		X
Eriogonum corymbosum Benth.	Umbrella Plant	N		X
Eriogonum lonchophyllum T & G	Umbrella Plant	N		X
Eriogonum salicinum Greene	Umbrella Plant	N		X
Eriogonum sp.	Umbrella Plant	N		X
Eriogonum subreniforme S. Wats	Eriogonum	N		X
Eriogonum umbellatum Torr.	Umbrella Plant	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Erodium cicutarium (L.) Lher. ex Ait.	Filaree	E	X	X
Erysimum argillosum (Greene) Rybd.	Wallflower	N		
Erysimum asperum (Nutt.) DC	Western Wallflower	N		
Euphorbia robusta (Engelm.) Small	Spurge	N		
Festuca sp.	Fescue	N	X	
Fragaria virginiana Duchesne	Wild Strawberry	N	X	X
Galium aparine L. Cleavers	Bedstraw	N	X	X
Galium bifolium L.	Bedstraw Cleavers	N		X
Galium boreale L.	Bedstraw	N		X
Galium coloradoensis W.F. Wright	Bedstraw	N		X
Geranium fremontii Torr. ex A. Gray	Geranium	N		X
Geranium richardsonni Fisch. & Trautu.	White Geranium	N		X
Geum aleppicum Jacq. spp. Strictum (A.T.) R.T. Clausen	Avens	N		
Gilia sp.	Gilia	N	X	X
Glycyrrhiza lepidota Pursh.	Wild Licorice	N	X	X
Grindelia squarrosa (Pursh) Dunal.	Curly-cup Gumweed	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Gymnolomia multiflora (Nutt.) B. et H.	Goldeneye	N	X	
Hackelia florabunda (Lehm.) Johnston	False Forget-me-not	N		X
Halogeton glomeratus (Bieb.) Mey.	Halogeton	E		
Haplopappus nuttallii T. et G.	Goldenweed	N		X
Haplopappus sp.	Goldenweed	N		X
Haplopappus spinulosus (Pursh) DC. var. australis (Greene) Rydb.	Iron Plant Goldenweed	N		X
Hedysarum boreale Nutt.	Sweet Vetch	N	X	X
Helenium hoopesii A. Gray	Sneezeweed Orange Sneezeweed	N		
Helianthella uniflora (Nutt.) T & G.	Little Sunflower Aspen Sunflower	N		X
Helianthus annuus L.	Sunflower	N	X	X
Heracleum lanatum Michx.	Cow parsnip	N	X	X
Heterotheca villosa (Pursh) Shinners.	Golden Aster	N		
Heuchera parvifolia Nutt. ex T. et G.	Alum-root	N		X
Hilaria jamesii (Torr.) Benth	Galleta-Grass	N		
Hordeum jubatum L.	Foxtail Barley	E		X
Humulus lupulus var. Neomexicanus A. Nels. & Cockerell	Wild Hops, Hops Common Hops	N	X	

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Hymenoxis acaulis (Pursh) Parker Var. Caespitosus (A. Nels.) Parker	Actinea	N		X
Iliamna rivularis (Dougl.) Greene	Mt. Hollyhock, Maplemallow Globemallow	N		
Ipomopsis aggregata (Pursh) V. Grant	Scarlet Gilia	N		
Iva xanthifolia Nutt.	Marshelder	N		
Juncus articus Willd.	Rush	N		X
Kochia iranica Bornm	Burning Bush	N		
Kochia scoparia (L.) Schrad.	Summer Cypress (Tumbleweed)	E		
Koeleria cristata (L.) Pers.	Junegrass	N		X
Koeleria gracilis Pers.	Junegrass	N		
Kuhnia eupatorides L.	False Boneset	N		
Lactuca pulchella (Pursh) DC	Blue Wild Lettuce	N	X	X
Lactuca serriola L.	Wild Lettuce	E	X	X
Lappula redowskii (Hornem.) Greene.	Stickseed	N		X
Lathyrus leucanthus Rydb.	White flowered Peavine	N		X
Lepidium densiflorum Schrad.	Peppergrass	N		X
Lepidium montanum Nutt.	Mountain Peppergrass	N	X	X
Lepidium perfoliatum L.	Clasping Peppergrass	E		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Leptodactylon pungens (Torr.) Rydb.	Prickly Gilia	N		X
Ligularia pudica (Greene) Weber	Butterweed	N		
Ligusticum porteri C. et R.	Lovage	N		X
Linum lewisii Pursh.	Wild Flax	N		
Lithospermum ruderale Lehm.	Gromwell	N	X	X
Lithospermum sp.	Gromwell	N	X	X
Lolium perenne L.	Perennial Wild Rye	E		
Lomatium grayi C. et R.	Biscuitroot	N	X	X
Lupinus caudatus Kellog spp. Argophyllus (A. Gray) Phillips	Lupine	N		X
Lupinus kingii S. Wats.	Lupine	N		X
Lupinus sp.	Lupine	N		X
Lygodesmia grandiflora (Nutt.) T. et G.	Skeleton Weed	N	X	
Machaeranthera leucanthemifolia (Greene) Greene	Aster	N		
Machaeranthera sp.	Aster	N		
Mahonia repens (Lindl.) G. Don.	Oregon Grape	N	X	X
Malcolmia africana (L.) R. Br.	Malcolmia	E		
Marrubium vulgare L.	Horehound	E		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Medicago lupulina L.	Black Medic	E	X	X
Medicago sativa L.	Alfalfa	E	X	X
Melilotus alba Desr.	White Sweet Clover	E		X
Melilotus officinalis (L.) Lam.	Yellow Sweet Clover	E		X
Mentha arvensis L.	Field Mint	N	X	X
Mentzelia rusbyi Wooton	Blazing Star	N		
Mentzelia montana (Davidson) Davidson.	Small-flowered Mentzelia	N		
Mentzelia multiflora (Nutt.) A. Gray.	Yellow Evening-Star	N		
Mertensia sp.	Bluebells	N		X
Microseris nutans (Geyer) Schultz-Bip.	False Dandelion	N	X	X
Mimulus guttatus DC.	Yellow Monkey Flower	N	X	
Monolepis nuttalliana (Schult.) Greene	Povertyweed	N	X	
Muhlenbergia sp.	Muhly	N		X
Nepeta cataria L.	Catnip	E	X	X
Oenothera caespitosa Nutt. ex. Fraser.	Gumbo Lily	N	X	X
Oenothera strigosa (Rydb.) Mack. et Bush.	Yellow Evening Primrose	N	X	X
Oenothera trichocalyx Nutt. ex. T. et G.	Evening Primrose	N	X	X
Onosmodium molle Michx. var. occidentalis (Mack.) Johnston.	False Gromwell	N		

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Opuntia erinacea (Engelm. et Bigelow) Coulter.	Prickly Pear Cactus	N	X	X
Opuntia fragilis (Nutt.) Haw.	Brittle Cactus	N	X	X
Opuntia polyacantha Haw.	Prickly Pear Cactus	N	X	X
Orobanche fasciculata Nutt.	Broom-Rape, Cancer-Root	N	X	
Orobanche uniflora L. var. sedi (Suksd.) Achey.	One flowered Cancer Root	N		
Oryzopsis hymenoides (R. et S.) Ricker	Indian Ricegrass	N	X	X
Oryzopsis micrantha (Trin. & Rupr.) Thurber	Little seed Ricegrass	N		
Osmorhiza depauperata Phil.	Sweet Cicely	N	X	X
Osmorhiza occidentalis (Nutt.) Torr.	Sweet Cicely	N	X	X
Oxytropis lambertii Pursh.	Lambert's Locoweed	N		X
Oxytropis lambertii var. bigelovii A. Gray.	Locoweed Colorado Locoweed	N	X	X
Panicum capillare L.	Witchgrass	N	X	
Parietaria pensylvanica Muehl. ex. Willd.	Pellitory	N		
Pediocactus simpsonii (Engelm.) Britton et Rose	Barrel Cactus	N		
Penstemon caesptitosus Nutt. ex A. Gray	Mat Penstemon	N		X
Penstemon comarrhenus A. Gray	Penstemon	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Penstemon lentus Pennell	Penstemon	N		X
Penstemon moffatii Eastw.	Penstemon	N		X
Penstemon osterhoutii pennell	Beard Tongue	N		X
Penstemon strictus Benth. in DC. ssp. strictiformis (Rydb.) Keck.	Penstemon	N		X
Penstemon teucrioides Greene	Beard Tongue	N		X
Penstemon Watsonii A. Gray	Beard Tongue	N		X
Phacelia heterophylla Pursh.	Scorpion weed	N		X
Phacelia idahoensis Henderson	Scorpion Weed	N		X
Phalaris arundinacea L.	Reed Canary Grass	E		
Phleum pratense L.	Timothy	N		X
Phlox Hoodii Rich.	Moss Phlox	N		X
Phlox longifolia Nutt.	Long-leaved Phlox (Sweet William)	N	X	
Phoradendron juniperinum Engelm.	Mistletoe	N	X	
Phragmites australis (Cav.) Trin. ex Stend.	Common Reed	N	X	
Physalis virginiana Mill.	Ground Cherry	N	X	X
Physaria floribunda Rydb.	Double Bladderpod	N		
Plantago elongata Pursh.	Slender Plantain	E	X	X
Plantago lanceolata L.	Narrow leaf Plantain	E	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Platyschkuhria integrifolia (A. Gray) Rydb.	Bahia	N		
Poa agassizensis, Boivin & D. Loeve	Bluegrass	N		
Poa canbyi (Scribn.) Piper	Canby Bluegrass	N		
Poa epilis Scribn.	Skyline Bluegrass	N		
Poa fendleriana (Steud.) Vasey	Mutton Bluegrass	N		X
Poa interior Rydb.	Inland Bluegrass	N		
Poa nervosa (Hook.) Vasey	Wheeler Bluegrass	N		
Poa palustris L.	Fowl Bluegrass	N		X
Poa pretensis L.	Kentucky Bluegrass	E		X
Poa secunda Prese.	Sandberg Bluegrass	N		X
Poa spp.	Several species noted in area, positive identification is uncertain		X	X
Polygonum douglasii Greene	Knotweed	N	X	X
Polygonum rurivagum Jordan	Devil's Shoestrings	E	X	X
Polypogon monspeliensis (L.) Desf.	Rabbit foot grass	E	X	
Portulaca oleracea L.	Common Purslane	E	X	
Potentilla gracilis var. pulcherriam (Lehm.) Fernald.	Cinquefoil	N		X
Potentilla quinquifolia Rydb.	Cinquefoil	N	X	

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Ranunculus cymbalaria Pursh.	Crowfoot	N	X	X
Ranunculus inamoenus Greene	Buttercup, Crowfoot	N	X	X
Ranunculus macounii Britton.	Macoun's Buttercup	N	X	X
Rorippa sp.	Cress	N	X	X
Rudbeckia occidentalis Nutt. var. montana (A. Gray) Perdue.	Cone-flower	N		X
Rumex crispus L.	Curly Dock	E	X	X
Salsola iberica Sennin & Pav.	Russian Thistle	E		
Schoenocrambe linifolia (Nutt.) Greene.	Hedge or Plains' Mustard	N		X
Scirpus acutus Muehl. ex Bigelow.	Soft Stemmed Bullrush	N	X	X
Scirpus americanus Pers.	Chairmaker's Rush	N		X
Scrophularia lanceolata Pursh.	Figwort	N		X
Senecio eremophilus Rydb. var. Kingii (Rydb.) Greene	Ragwort	N		X
Senecio fendleri A. Gray	Golden Ragwort	N		X
Senecio integerrimus Nutt.	Ragwort, Butterweed	N		X
Senecio multilobatus T. et G. A. Gray	Ragwort	N		X
Senecio mutabilis Greene.	Ragwort, Butter-weed, Groundsel	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Senecio wootonii Greene.	Groundsel, Ragwort	N		X
Setaria viridis (L.) Beauv.	Green Foxtail	E		
Sidalcea candida A. Gray	White Checker-mallow	N	X	X
Silene scouleri ssp. Hallii (S. Wats.) C. L. Hitchcock and Maguire	Catchfly, Campion	N		
Sinapis arvensis L.	Charlock	E		
Sisymbrium altissimum L.	Jim Hill Mustard	N	X	X
Sisymbrium elegans (Jones) Payson.	Hedge Mustard	N		X
Sitanion hystrix (Nutt.) J. G. Smith	Squirrel tail	N		X
Sitanion longifolium J. G. Smith	Squirreltail grass	N		X
Smilacina racemosa (L.) Desf.	False Solomon's Seal	N	X	X
Smilacina stellata (L.) Desf.	False Solomon's Seal	N	X	X
Solidago canadensis L.	Goldenrod	N	X	X
Solidago sparsiflora A. Gray	Goldenrod	N		X
Sonchus asper (L.) Hill	Sow-Thistle	E	X	
Sphaeralcea coccinea (Pursh) Rydb.	Scarlet Globe Mallow	N		X
Sporobolus asper (Michx.) Kunth.	Dropseed	N	X	X
Sporobolus cryptandrus (Torr.) A. Gray	Sand Dropseed	N	X	X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Stanleya pinnata (Pursh.) Britton.	Prince's Plume	N	X	
Stipa comata Trin. and Rupr.	Needle and Thread grass	N		X
Stipa lettermanii Vasey	Letterman's needlegrass	N		X
Stipa viridula Trin.	Green Needle Grass	N		X
Streptanthus cordatus Nutt. ex T. et G.	Twistflower	N		
Suaeda fruticosa (L.) Forsk.	Seablite	E	X	
Sullivantia purpusi (Brand) Rosendahl.	Sullivantia	N		
Taraxacum laevigatum (Willd.) DC	Dandelion, Blowballs	E		X
Taraxacum officinale Web. in Wiggers.	Dandelion	E	X	X
Thalictrum dasycarpum Fisch. & Lall. ex Fisch. may Lall	Purple Meadow-rue	N		
Thalictrum fendleri Engelm. ex A. Gray	Meadow Rue	N		X
Thelypodium sagittatum (Nutt.) Endl.	Thelypodium	N		X
Thermopsis montana Nutt. ex T. & G.	Mountain Thermopsis	N		X
Thlaspi arvense L.	Penny Cress	E	X	X
Thlaspi montanum L.	Penny Cress, Wild Candytuft	N		X
Townsendia hookeri Beamen	Easter Daisy	N		X

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Tragopogan dubius Scop.	Goat's Beard	E	X	X
Tragopogan dubius ssp. major (Jacq.) Vollman	Salsify, Oyster plant, Goat's Beard	E		X
Trifolium gymnocarpon Nutt.	Clover	N	X	X
Trifolium pratense L.	Red Clover	E	X	X
Trifolium repens L.	White Clover	E	X	X
Typha latifolia L.	Cattail	N	X	
Urtica dioica L.	Stinging Nettle	N	X	X
Valeriana occidentalis Heller.	Valerian, Garden Heliotrope	N	X	X
Verbascum thapsus L.	Common mullein	E		X
Verbena bracteata Lag. et Rodr.	Creeping Charlie	E		
Veronica salina Schur.	Speedwell	E	X	
Vicia Americana Muehl. ex Willd.	Vetch	N		X
Viola adunca Smith.	Mountain Blue Violet	N		X
Viola canadensis L. var. rugulosa (Greene) C. L. Hitchc.	Violet	N	X	X
Viola nuttallii Pursh.	Yellow violet	N		X
Viola utahensis Baker & Clausen.	Violet	N		X
Vulpia octoflora (Walt.) Rydb.	Six-weeks fescue	N		

HERBACEOUS LAYER

Latin Name	Common Name	Native/ Exotic	Edible Human	Edible Mule Deer
Xanthium strumarium L.	Cockle Burr	E		X
Yucca glauca Nutt.	Yucca	N	X	
Zygadenus venenosus S. Wats. var. gramineus (Rydb.) Walsh ex M. E. Peck	Death Camas	N		X

APPENDIX B

AVAILABILITY OF NATIVE PLANTS BY VEGETATION ZONE SUITABLE FOR HUMAN CONSUMPTION IN THE PICEANCE BASIN, COLORADO

[Native Species Only]

Sources

Ferchau, H. 1973a
Ferchau, H. 1973b
Keammerer, W. R. 1974
Ward, et al. 1974
Rio Blanco Oil Shale Project 1975

APPENDIX B

EDIBLE PLANT DISTRIBUTION BY ZONE
(HUMAN)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
TREE LAYER												
Acer negundo	X							X				
Juniperus osteosperma				X				X	X			
Pinus edulis Eng.						X		X	X			
Populus angustifolia James	X											
Populus sargentii Dode	X											
Populus tremuloides Michx.											X	X
Quercus gambelii Nutt.	X	X				X	X	X	X		X	
SHRUB LAYER												
Acer glabrum Torr.	X							X			X	
Amelanchier alnifolia Nutt.	X	X	X	X		X		X	X		X	X
Amelanchier pumila Nutt. ex T&G	X					X		X				
Artemisia tridentata Nutt.	X	X	X	X	X		X	X	X	X		
Atriplex canescans (Pursh) Nutt.		X		X			X	X		X		
A. confertifolia (T & F)	X	X	X	X	X		X		X	X		
A. nuttallii S. Wats.				X								
Ceanothus fendleri A. Gray		X					X	X				
Chrysothamnus viscidiflorus (Hock) Nutt		X		X			X		X			
Clematis ligusticifolia Nutt. T. & G.	X	X					X	X		X		
Eriogonum corymbosum Benth.		X		X		X	X	X	X	X		
Holodiscus dumosus (Nutt.) Heller						X		X		X		
Humulus lupulus L.	X											
Prunus virginiana L.	X	X				X	X	X		X	X	
Prunus sp. (Prob. *P. melanocarpa* (A. Nels. Rydb.)	X											
Rhus sp. (Prob. R. glabra L.)	X					X		X				
Rhus trilobata Nutt. T. & G.	X	X	X	X	X	X	X	X	X	X		

APPENDIX B (continued)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
SHRUB LAYER (continued)												
Ribes aureum Pursh	X	X					X	X		X		
Ribes cereum Dougl.						X		X			X	
Ribes inerme Rydb.	X											
Ribes viscosissimum Pursh	X					X		X	X	X	X	
Rosa woodsii Lindl.	X					X		X		X	X	
Rubus idaeus L.	X											
Salix interior Rowlee			X									
Sarcobatus vermiculatus (Hook.) Torr.	X	X	X	X	X		X		X			
Shepherdia argentea (Pursh) Nutt.	X											
Svida sericea (L.) Holub.	X					X		X				
HERBACEOUS LAYER												
Agoseris aurantiaca (Hook.) Greene	X											
Agropyron cristatum (L.) Gaertn.		X										
Agropyron smithii Rydb.	X		X					X				
Agropyron spicatum (Pursh) Scribn. et Smith		X										
Agropyron trachycaulum (Link) Malte		X	X	X			X	X	X	X		
Agrostis gigantea Roth	X							X				
Allium acuminatum Hook.		X					X					
Allium textile Nels, et. Macbr.		X					X					
Angelica ampla A. Nels.	X											
Antennaria alpina (L.) Gaertn											X	X
Antennaria parvifolia Nutt.								X				
Antennaria pulcherrima (Hook.) Greene								X				
Aquilegia caerulea James												X
Aquilegia micrantha Eastw.								X				
Arctium minus (Hill) Bernh.	X							X	X			

APPENDIX B (continued)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
HERBACEOUS LAYER (continued)												
Arctostaphylos patula Greene, Pitt.									X		X	
Artemisia dracunculus L.		X					X			X		
Artemisia frigida Willd.	X	X		X			X			X		
Artemisia ludcviciana Nutt.		X					X	X		X		
Asclepias speciosa Torr.	X											
Aster foliaceus Lindl. in D.C.	X							X				
Aster foliargus L.	X											
Aster glaucodes Blake	X											
Aster leavis L.	X											
Atriplex rosea L.		X	X	X								
Balsamorhiza sagittata (Pursh) Nutt.		X					X					
Bromus marginatus Nees					X							X
Calochortus nuttallii Torr.		X	X	X			X		X			
Carex deweyana Schwein	X										X	X
Carex geyeri Boott.								X	X		X	X
Carex occidentalis Bailey								X	X		X	X
Carex rossii Boott								X	X		X	X
Castilleja linariaefolia Benth. in D.C.		X		X			X					
Chenopodium fremontii S. Wats.						X		X				
Cirsium undulatum (Nutt.) Spreng.	X	X		X			X	X				
Cirsium sp.	X			X		X		X				
Cleome serrulata Pursh.	X											
Comandra umbellata (L.) Nutt.				X								
Cymopterus longipes S. Wats.									X			
Cymopterus purpureus S. Wats.				X					X			
Cyperus sp.	X	X					X					
Descurainia pinnata (Walt.)	X	X	X			X	X	X	X	X	X	

APPENDIX B (continued)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
HERBACEOUS LAYER (continued)												
Descurainia richardsonii (Sw.) O.E. Schulz	X											
Echinocereus triglochidiatus Engelm. var. melanacanthus (Engelm.) L. Benson		X	X				X		X			
Elymus canadensis L.	X											
Epilobium adenocaulon Hausskn.	X											
Epilobium brevistylum Barbey	X											
Equisetum arvense L.	X											
Equisetum variegatum Schleich.	X											
Eriogonum sp.			X	X		X		X				
Festuca sp.							X	X	X			
Fragaria virginiana Duchesne	X											
Galium aparine L. Cleavers	X	X					X	X				
Gilia sp.							X	X	X			
Glycyrrhiza lepidota (Nutt.) Pursh	X											
Gymnolomia multiflora (Nutt.) B. et H.	X	X					X					
Hedysarum boreale Nutt.									X			
Helianthus annuus L.	X	X	X	X			X	X	X	X		
Heracleum lanatum Michx.	X											
Humulus lupulus L. var. neomexicanus Nels and Cockerell						X		X				
Koeleria cristata (L.) Pers.						X	X	X	X			
Lactuca pulchella (Pursh) D.C.	X							X				
Lepidium montanum Nutt.		X	X	X		X	X	X	X	X		
Ligusticum porteri C. & R.						X		X		X		
Linum lewisii Pursh						X		X		X		
Lithospermum ruderale Lehm.		X	X				X					
Lithospermum sp.		X	X				X					
Lomatium grayi C. et R.									X			

APPENDIX B (continued)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
HERBACEOUS LAYER (continued)												
Lupinus sp.		X					X		X			
Lygodesmia grandiflora (Nutt.) T. et G.				X		X		X				
Mahonia repens (Lindl.) G. Don.	X	X				X	X	X	X		X	
Mentha arvensis L.	X											
Microseris nutans (Geyer) Schultz--Bip.	X											
Mimulus guttatus D.C.	X											
Monolepis nuttalliana (R. & S.) Greene		X										
Oenothera caespitosa Nutt. ex Fraser		X					X	X				
Oenothera strigosa (Rydb.) Mack. et Bush	X			X								
Oenothera trichocalyx Nutt. ex T. et G.	X											
Opuntia erinacea (Engelm. et Bigelow)	X	X	X	X			X		X	X		
Opuntia fragilis (Nutt.) Haw		X					X					
Opuntia polyacantha Haw.		X			X		X					
Orobanche fasciculata Nutt.		X					X					
Oryzopsis hymenoides (R. et S.) Ricker		X	X	X	X	X	X	X	X	X		
Osmorhiza depauperata Phil.	X											
Osmorhiza occidentalis (Nutt.) Torr.	X											
Oxytropis lambertii Pursh		X					X					
Oxytropis lambertii var. bigelowii A. Gray		X					X					
Panicum capillare L.	X											
Phlox longifolia Nutt.			X	X								
Phoradendron juniperinum Engelm.									X			
Phragmites australis (Cav.) Trin. ex Steud.	X											
Physalis virginiana Miller	X											
Poa fendleriana (Steud.) Vasey	X											

APPENDIX B (continued)

	RIPARIAN WOODLANDS	LOWLAND BIG SAGE SHRUB	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE & GRASSLAND	MOUNTAIN MAHOGANY	UPLAND BIG SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	HIGH ELEVATION GRASSLANDS	DOUGLAS FIR	ASPEN WOODLAND
HERBACEOUS LAYER (continued)												
Poa sp.	X	X	X				X	X	X	X		
Polygonum douglasii Greene	X		X					X	X			
Potentilla quinquifolia Rydb.	X											
Ranunculus cymbalaria Pursh	X											
Ranunculus inamoenus Greene	X											
Ranunculus macounii Britton	X											
Rorippa sp.	X											
Scirpus acutus Muehl ex Bigelow	X											
Sidalcea candida A. Gray	X							X				
Sisymbrium altissimum L.	X	X	X				X	X		X		
Smilacina racemosa (L.) Desf.											X	
Smilacina stellata (L.) Desf.	X							X				
Solidago canadensis L.	X							X				
Sporobolus asper (Michx.) Kunth	X				X							
Sporobolus cryptandrus (Torr.) A. Gray	X				X							
Stanleya pinnata (Pursh.) Britton	X		X			X						
Trifolium gymnocarpon Nutt.		X	X	X		X	X	X	X	X		
Typha latifolia L.	X											
Urtica dioica L.	X											
Valeriana occidentalis Heller						X		X		X		
Vicia Americana Muehl ex Willd.	X							X				
Viola canadensis L.	X											
Yucca glauca Nutt.		X		X		X	X		X	X		

APPENDIX C

MAMMALS OF THE PICEANCE CREEK BASIN, COLORADO

Sources

Cringan 1973
Baker and McKean 1971
McKean and Neil 1974a
McKean and Neil 1974b
McKean and Neil 1974c

APPENDIX C

FAUNAL RESOURCES OF THE PICEANCE BASIN

	LATIN NAME	COMMON NAME
BIG GAME	*Bison bison*	Buffalo
	Cervus canadensis	Elk
	Felis concolor	Mountain Lion
	Odocoileus hemionus	Mule Deer
	Odocoileus virginianus	White-tailed Deer
	Ovis canadensis	Mountain Sheep
	Ursus americanus	Black Bear
SMALL GAME	*Lepus americanus*	Snowshoe Hare
	Sylvilagus audubonii	Desert Cottontail
	Sylvilagus nuttallii	Nuttall's Cottontail Rabbit
	Tamiasciurus hudsonicus	Pine (red) Squirrel
FUR BEARERS	*Bassariscus astutus*	Ringtail
	Castor canadensis	Beaver
	Didelphis marsupialis	Opossum
	Lutra canadensis	River Otter
	Mustela erminea	Ermine
	Mustela frenata	Long-tailed Weasel
	Mustela nigripes	Black-footed Ferret
	Mustela vison	Mink
	Ondatra zibethicus	Muskrat
NON GAME	*Ammospermophilus leucurus*	White-tailed Antelope Squirrel
	Antrozous pallidus	Pallid Bat
	Canis latrans	Coyote
	Canis lupus	Gray wolf
	Clethrionomys grapperi	Gapper's red-back Vole
	Cynomys leucurus	White-tailed Prairie Dog

APPENDIX C (continued)

	LATIN NAME	COMMON NAME
NON GAME Cont.	*Dipodomys ordii*	Ord's Kangaroo Rat
	Eptesicus fuscus	Big Brown Bat
	Equus caballus	Wild Horse
	Erethizon dorsatum	Porcupine
	Eutamias minimus	Least Chipmunk
	Eutamias quadrivittatus	Colorado Chipmunk
	Eutamias umbrinus	Uinta Chipmunk
	Lagurus curtatus	Sagebrush Vole
	Lasionycteris noctivagans	Silver-haired Bat
	Lasiurus cinereus	Hoary Bat
	Lepus californicus	Black-tailed Jack Rabbit
	Lepus townsendii	White-tailed Jack Rabbit
	Lynx rufus	Bobcat (Wildcat)
	Marmota flaviventris	Yellow-bellied Mormot
	Mephitis mephitis	Striped Skunk
	Microtus longicaudus	Long-tailed Vole
	Microtus montanus	Montane Vole
	Microtus pennsylvanicus	Meadow Vole
	Mus musculus	House Mouse
	Myotis californicus	California Myotis
	Myotis evotis	Long-eared Bat
	Myotis leibii	Small-footed Myotis
	Myotis lucifugus	Little Brown Bat
	Myotis sp.	Spotted Bat
	Myotis thysanodes	Fringed Bat
	Myotis volans	Long-legged Myotis
	Neotoma cinerea	Bushy-tailed Wood Rat
	Neotoma lepida	Desert Wood Rat
	Onychomys leucigaster	Northern Grasshopper Mouse
	Perognathus apache	Apache Pocket Mouse
	Peromyscus boylii	Brush Mouse

APPENDIX C (continued)

	LATIN NAME	COMMON NAME
NON GAME Cont.	Peromyscus crinitus	Canyon Mouse
	Peromyscus difficilis	Rock Mouse
	Peromyscus maniculatus	Deer Mouse
	Peromyscus truei	Pinon Mouse
	Pipistrellus hesperus	Western Pipistrelle
	Plecyus townsendii	Townsend's Big-eared Bat
	Procyon lotor	Raccoon
	Reithrodontomys megalotis	Western Harvest Mouse
	Sorex cinereus	Masked Shrew
	Sorex merriami	Merriam's Shrew
	Sorex nanus	Dwarf Shrew
	Sorex palustris	Water Shrew
	Sorex vagrans	Vagrant Shrew
	Spermophilus lateralis	Golden-mantled Ground Squirrel
	Spermophilus richardsonni	Richardson's Ground Squirrel
	Spermophilus tridecemlineatus	Thirteen-lined Ground Squirrel
	Spermophilus variegatus	Rock Squirrel
	Spilogale putorius	Spotted Skunk
	Tadarida brasiliensis	Brazilian Free-tailed Bat
	Taxidea taxus	American Badger
	Thomomys talpoides	Northern Pocket Gopher
	Urocyon cinereoargenteus	Gray Fox
	Ursus arctos	Grizzly Bear
	Vulpes vulpes	Red Fox
	Vulpes velox	Kit (Swift) Fox
	Zapus princeps	Western Jumping Mouse

APPENDIX D

AVAILABILITY OF NATIVE PLANTS BY VEGETATION ZONE SUITABLE FOR MULE DEER CONSUMPTION IN THE PICEANCE BASIN, COLORADO

Sources

Ferchau 1973a
Ferchau 1973b
Keammerer 1974
Ward, et al. 1974
Rio Blanco Oil Shale Project 1975

APPENDIX D

EDIBLE PLANT DISTRIBUTION BY ZONE (MULE DEER)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
TREE LAYER												
Acer negundo								X				
Juniperus osteosperma				X				X	X			
Pinus edulis						X		X	X			
Populus angustifolia	X											
Populus sargentii	X											
Populus tremuloides											X	X
Pseudotsuga menziesii											X	X
Quercus gambellii	X	X				X	X	X	X		X	
SHRUB LAYER												
Acer glabrum	X							X			X	
Amelanchier sp.	X					X		X				
Amelanchier alnifolia	X	X	X	X		X	X	X	X		X	X
Amelanchier utahensis	X	X	X	X		X	X	X	X		X	X
Artemisia sp.	X	X	X	X	X		X	X	X	X		
Artemisia tridentata	X	X	X	X	X		X	X	X	X		
Atriplex canescens		X		X			X	X		X		
Atriplex confertifolia	X	X	X	X	X		X		X	X		
Atriplex nuttallii				X								
Betula fontinalis	X											
Ceanothus fendleri		X					X	X				
Ceanothus velutinus		X					X	X				
Cercocarpus sp.						X		X				
Cercocarpus montanus						X		X				
Chrysothamnus nauseosus	X	X	X	X		X	X	X				
Chrysothamnus viscidiflorus		X		X			X		X			
Ephedra viridis				X		X		X	X			
Eurotia lanata									X			

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
SHRUB LAYER (continued)												
Holodiscus dumosus						X		X		X		
Pachystima myrsinites						X					X	
Prunus sp.	X											
Prunus virginiana	X	X				X	X	X		X	X	
Purshia tridentata						X		X				
Rhus glabra	X					X		X				
Rhus trilobata	X	X	X	X		X	X	X	X	X	X	
Ribes sp.	X	X				X	X	X		X	X	
Ribes aureum	X	X					X	X		X		
Ribes cereum						X		X			X	
Rosa woodsii	X					X	X			X	X	
Rubus idaeus	X											
Salix sp.	X		X									
Salix exigua	X		X									
Sarcobatus vermiculatus	X	X	X	X	X		X		X			
Shepherdia argentea	X											
Symphoricarpos oreophilus						X		X			X	
Tetradymia canescens		X	X	X			X					
HERBACEOUS LAYER												
Agastache urticifolia Kuntze	X											
Agoseris glauca (Pursh) Raf.												
Agropyron cristatum L.		X										
Agropyron smithii	X		X					X				
Agropyron spicatum		X										
Agrostis gigantea	X							X				
Allium acuminatum Hook		X					X					
Allium textile nels		X					X					
Amaranthus graecizans L.	X											

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Ameranthus retroflexus L.	X											
Androsace septentrionalis		X					X					
Antennaria parviflora								X				
Aquilegia caerulea												X
Aquilegia micrantha												X
Arabis drummondi								X	X	X		
Arenaria sp.												
2 possibilities--Fendleri		X					X					
Congesta		X					X					
Artemisia dracunculus		X					X			X		
Artemisia frigida	X	X		X			X			X		
Artemisia ludoviciana		X						X		X		
Arnica cordifolia								X	X		X	
Aster foliaceus	X							X				
Atriplex rosea L.		X	X	X								
Balsamorhiza sagittata		X					X					
Brickellia grandiflora												
Bromus ciliatus	X	X	X	X	X	X	X	X	X	X	X	X
Bromus inermis	X	X	X	X	X	X	X	X	X	X	X	X
Bromus tectorum	X	X	X	X	X	X	X	X	X	X	X	X
Calochortus nuttallii		X	X	X			X		X			
Capsella bursa-pastoris	X											
Carex geyerii								X	X		X	X
Castilleja linariaefolia		X		X			X					
Chaenactis sp.						X		X				
Chenopodium sp.	X	X				X	X	X	X	X		
Chenopodium album	X	X				X	X	X	X	X		
Cirsium arrense	X							X				
Cirsium sp.	X			X		X		X				
Cirsium undulatum	X	X		X			X	X				
Clematis hirsutissima						X		X				

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Clematis ligusticifolia	X											
Collinsia parviflora									X			
Collomia linearis										X		
Comandra umbellata	X	X					X					
Convolvulus sp. (Arvense)	X											
Conyza canadensis	X											
Crepis acuminta		X					X					
Crepis sp.		X					X					
Cryptantha sp.		X					X					
Cymopterus purpureus				X					X			
Cymopterus sp.				X					X			
Cynoglossum officinale	X											
Cyperus sp.	X	X										
Dactylis glomerata	X											
Delphinium sp.		X					X					
Descurainia pinnata	X	X	X			X	X	X	X	X	X	
Descurainia sp.	X											
Draba sp.		X					X		X			
Elymus cinereus		X					X					
Epilobium sp.	X											
Equisetum sp.	X											
Erigeron sp.		X					X					
Erigeron caespitous		X					X					
Erigeron formo sisimus		X					X					
Eriogonum sp.			X	X		X		X				
Eriogonum umbellatum						X		X				
Erodium circutarium	X		X									
Festuca sp.							X	X	X			
Fragaria virginiana	X											
Galium sp.	X	X						X				
Galium boreale											X	

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Geranium fremontii	X											
Geranium richardsonii	X											
Gilia sp.							X	X	X			
Glycyrrhiza lepidota	X											
Grindelia squarrosa	X		X									
Hackelia sp.	X											
Haplopappus nuttallii				X					X			
Haplopappus spinulosus				X					X			
Hedysarum sp.								X	X			
Helianthella uniflora										X		
Helianthus annuus	X	X	X	X			X	X	X	X		
Heracleum lanatum	X											
Heuchera sp.											X	
Hordeum jubatum	X											
Hymenoxys acaulis			X	X								
Juncus sp.	X											
Koeleria cristata						X	X	X	X			
Lactuca pulchella	X							X				
Lactuca serriola	X	X	X				X					
Lappula redowskii		X					X					
Lathyrus leucanthus											X	
Lepidium sp.		X	X	X		X	X	X	X	X		
Leptodactylon pungens		X					X					
Ligusticum porteri						X		X		X	X	
Lithospermum ruderale		X	X				X					
Lomatium grayi		X	X									
Lupinus sp.		X					X		X			
Lupinus caudatus		X					X					
Lupinus kingii									X			
Mahonia repens	X	X				X	X	X	X		X	
Marrubium vulgare		X					X					

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Medicago lupulina	X									X		
Medicago sativa	X	X	X									
Melilotus alba	X											
Melilotus officinalis	X											
Mentha arvensis	X											
Mertensia sp.	X											
Microseris nutans	X											
Muhlenbergia sp.	X	X					X					
Nepeta cataria	X	X						X				
Oenothera sp.	X	X		X			X					
Oenothera caespitosa		X					X	X				
Oenothera strigosa	X											
Oenothera trichocalyx	X											
Opuntia erinacea	X	X	X	X		X	X		X	X		
Opuntia fragilis		X					X					
Opuntia polyacantha		X			X		X					
Oryzopsis hymenoides		X	X	X	X	X	X	X	X	X		
Osmorhiza sp.	X											
Osmorhiza depauperata	X											
Oxytropis lambertii		X										
Penstemon sp.		X					X					
Penstemon caesptitosus		X					X					
Penstemon watsonii		X					X					
Phacelia heterophylla						X		X				
Phacelia idahoensis	X											
Phleum pratense	X											
Phlox hoodii									X			
Physalis virginiana	X											
Plantogo elongata			X									
Plantogo leñceolata	X		X									

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Poa sp.	X	X	X				X	X	X	X		
Poa fendleriana	X								X		X	
Poa palustris	X								X		X	X
Poa pretensis	X											
Poa secunda	X								X		X	
Polygonum douglasii	X		X					X	X			
Polygonum rurivagum	X											
Portulaca oleracea	X											
Potentilla gracilis												
Ranunculus	X											
Ranunculus cymbalaria	X											
Rorippa sp.	X											
Rudbeckia occidentalis	X											
Rumex sp.	X		X					X				
Schoenocrambe linifolia												
Scirpus acutus	X		X									
Scirpus americanus	X											
Scrophularia lanceolata	X											
Senecio sp.								X				
Senecio integerrimus	X											
Senecio multilobatus								X				
Sidalcea sp.	X							X				
Sisymbrium sp.	X	X	X				X	X		X		
Sisymbrium altissimum	X	X	X				X	X		X		
Sitanion sp.	X	X	X				X	X		X		
Sitanion hystrix	X	X	X				X	X		X		
Smilacina racemosa											X	
Smilacina stellata	X							X				
Solidago canadensis	X							X				
Solidago sporsiflora		X					X					

APPENDIX D (continued)

	RIPARIAN	LOWLAND BIG SAGE	GREASEWOOD	SALTBUSH	HILLSIDE FRINGED SAGE	MOUNTAIN MAHOGANY	UPLAND SAGE	MIXED MOUNTAIN SHRUB	PINON/JUNIPER	INDIAN RICE GRASS	DOUGLAS FIR	ASPEN
HERBACEOUS LAYER (continued)												
Sphaeralcea coccinea		X	X				X					
Sporobolus asper	X											
Sporobolus cryptandrus	X											
Stipa comata		X					X					
Stipa lettermanii	X											
Stipa viridula	X											
Taraxacum laevigatum		X					X				X	
Taraxacum officinale	X	X						X			X	
Thalictrum fendleri							X					
Thelypodium sagittatum						X		X				
Thermopsis montana	X											
Thlaspi arvense	X											
Thlaspi montanum	X											
Townsendia hookeri						X		X				
Tragopogon dubius	X	X	X				X	X		X		
Trifolium gymnocarpon		X	X	X		X	X	X	X	X		
Trifolium pratense	X											
Trifolium repens	X											
Urtica dioica	X											
Valeriana occidentalis						X		X		X		
Verbascum thapsus	X											
Vicia americana	X							X				
Viola adunca	X											
Viola canadensis	X											
Viola nuttallii		X					X					
Viola utahensis		X					X					
Xanthium strumarium	X											
Zygadenus veneuosus		X					X					

APPENDIX E

STATISTICAL FORMULAE

APPENDIX E

STATISTICAL FORMULAE

NAME	FORMULA	TEXT PAGE & REFERENCE
Nearest Neighbor Statistic	$R_n = 2\bar{d}\sqrt{\frac{n}{a}}$ Where: $\bar{d}$ = mean distance between points and their nearest neighbor a = area concerned n = number of points $R = 0$ maximum cluster $R = 1$ random distribution $R = 2.15$ maximum dispersion	pp. 122-125 Theakstone & Harrison (1970)
Chi Square	$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$ Where: O_i = observed frequency E_i = expected frequency Compare the derived chi square value to a table of the chi square distribution to determine level of significance.	pp. 118-120 HP 25 Applications book (1975) For Chi Square Distribution Table V Weinberg and Schumaker (1969)

APPENDIX E (continued)

NAME	FORMULA	TEXT PAGE & REFERENCE
Pearson's Coefficient of Variation	$V = \frac{\sigma}{\bar{X}} 100$	Page 45 Arkin and Colton (1970)

Where:

V = variability expressed as a percentage

σ = standard deviation

$\bar{X}$ = mean value of factor being tested

NAME	FORMULA	TEXT PAGE & REFERENCE
Spearman's Rank Correlation	$R_s = 1 - \frac{6 \sum_{i=1}^{n} D_i^2}{n(n^2-1)}$	pp. 113-115 HP 55 Statistics Programs (1974) *

Where:

n = number of paired observations

D_1 = Rank (X_i)-Rank (Y_i)

If the X and Y random variables from which these n pairs of observations are derived are independent, then R_s has zero mean and a variance

$$\frac{1}{n-1}$$

APPENDIX E (continued)

NAME	FORMULA	TEXT PAGE & REFERENCE

Spearman's Rank Correlation (continued)

A score of $R_s = +1.0$ indicates complete agreement in rank order while a score of $R_s = -1.0$ indicates complete agreement in opposite order.

Test for null hypothesis

H_o: X,Y are independent is using $z = R_s\sqrt{n-1}$.

Table II
Weinberg and
Schumaker
(1969)

*The program contained in this manual was rewritten for use with the HP 25 calculator.

APPENDIX F

SITES AND THEIR CATCHMENTS CHOSEN FOR CATCHMENT ANALYSIS

VEGETATION KEY (NAVAL OIL SHALE RESERVE)

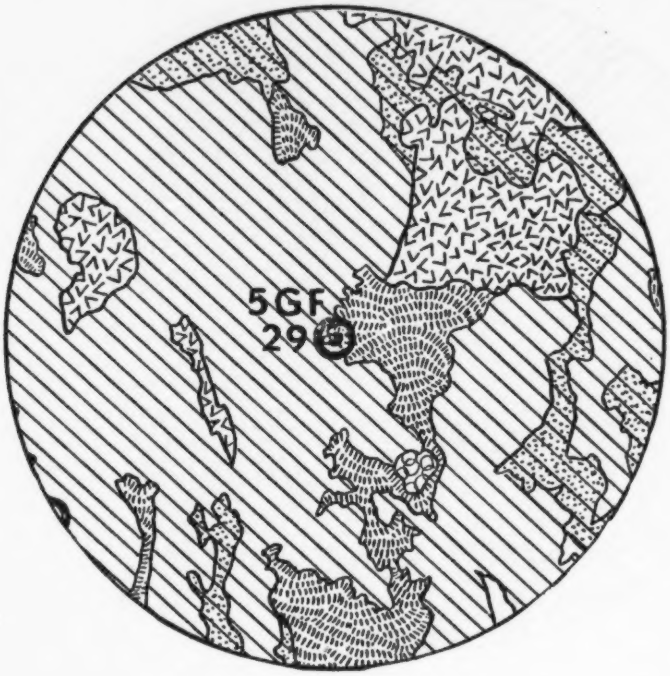
▦	DOUGLAS FIR AND ASPEN
▧	MIXED MOUNTAIN SHRUBLAND
▩	UPLAND BIG SAGEBRUSH SHRUBLAND
▨	HILLSIDE FRINGED SAGE AND GRASSLAND
☐	BARE SLOPE
〰	BOUNDARY
▒	HIGH ELEVATION GRASSLAND

NAVAL OIL SHALE RESERVE

Site Number 5GF 29

Catchment Radius: 1 kilometer

Site Function: Camp Site



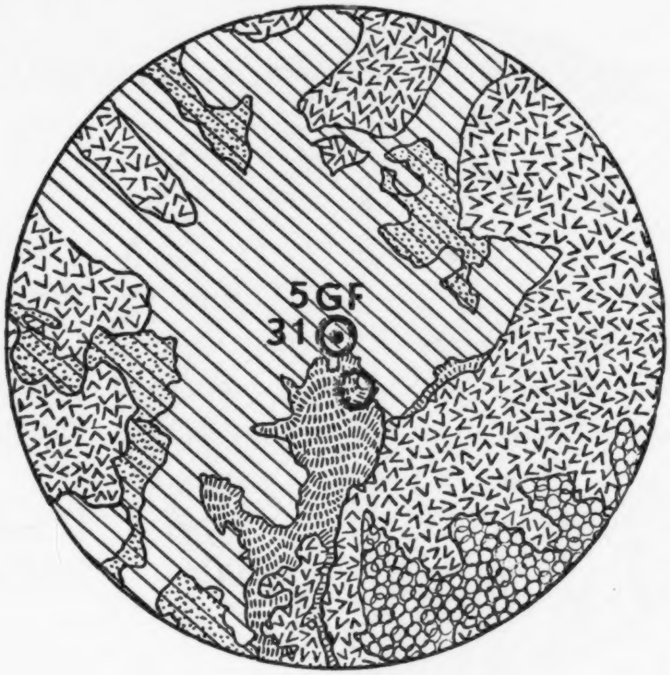
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	66
Douglas Fir/Aspen Woodland	14
Upland Big Sagebrush Shrubland	0
High Elevation Grasslands	9
Hillside Fringed Sage and Grassland	11
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 31

Catchment Radius: 1 kilometer

Site Function: Camp Site



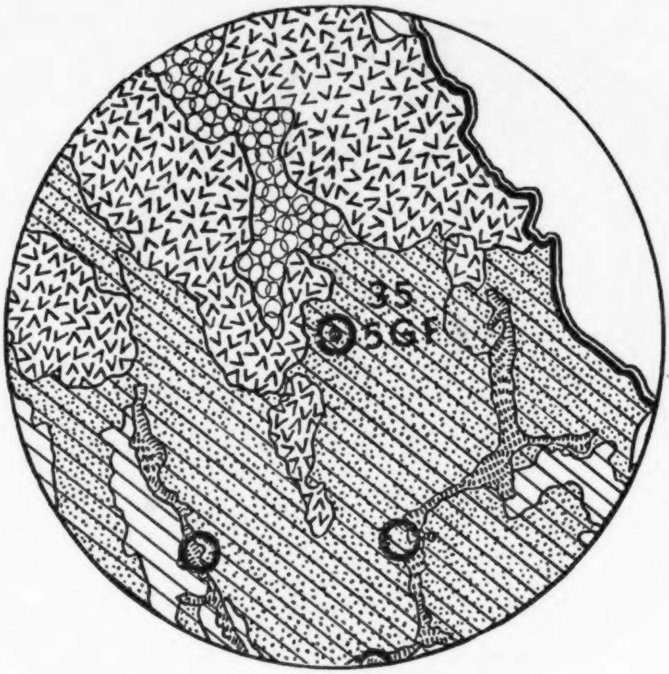
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	43
Douglas Fir/Aspen Woodland	37
Upland Big Sagebrush Shrubland	5
High Elevation Grasslands	7
Hillside Fringed Sage and Grassland	8
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 35

Catchment Radius: 1 kilometer

Site Function: Food Processing Area



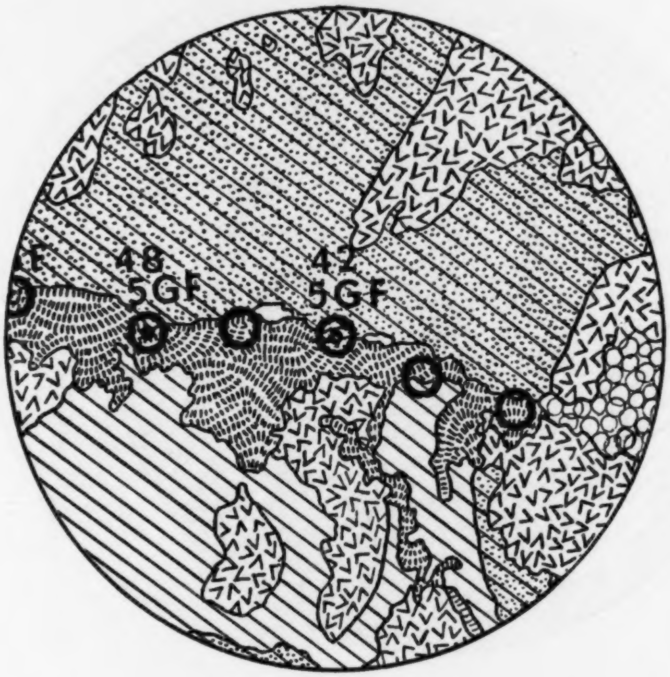
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	7
Douglas Fir/Aspen Woodland	27
Upland Big Sagebrush Shrubland	46
High Elevation Grasslands	8
Hillside Fringed Sage and Grassland	0
Bare Slope	0
Boundary	12

NAVAL OIL SHALE RESERVE

Site Number 5GF 42

Catchment Radius: 1 kilometer

Site Function: Camp Site



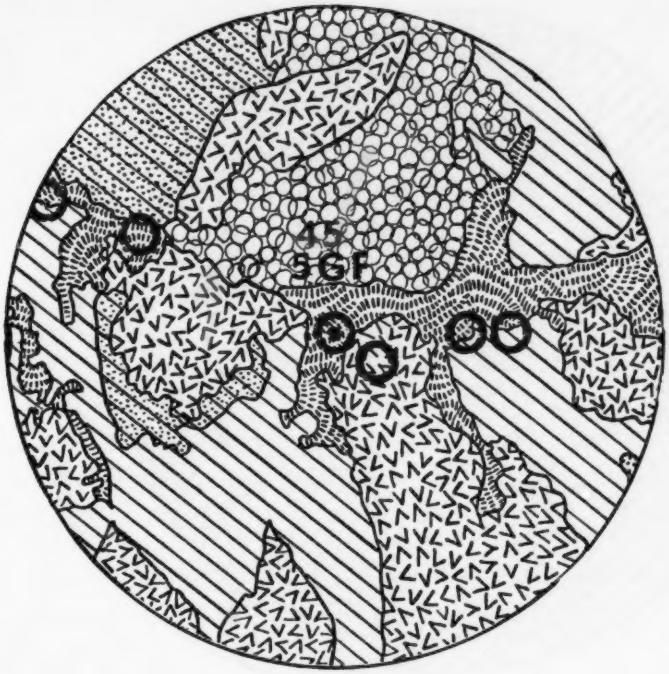
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	22
Douglas Fir/Aspen Woodland	28
Upland Big Sagebrush Shrubland	0
High Elevation Grasslands	12
Hillside Fringed Sage and Grassland	37
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 45

Catchment Radius: 1 kilometer

Site Function: Temporary Camp



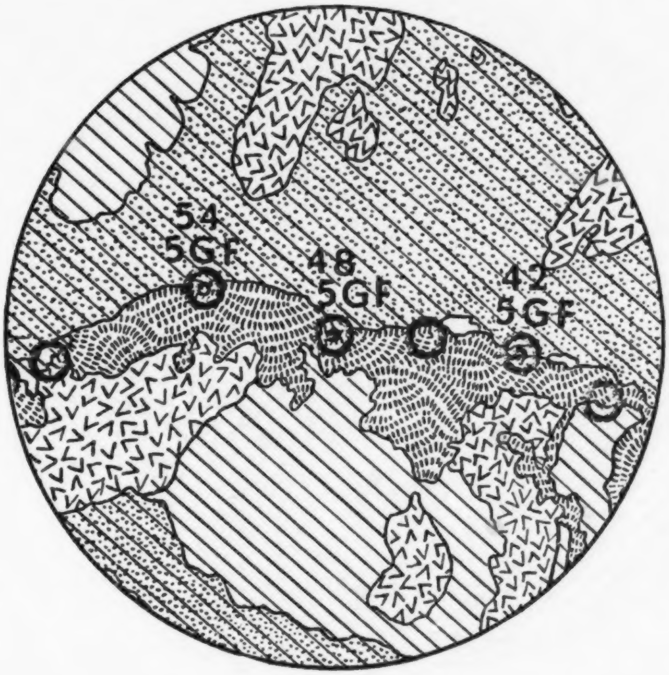
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	35
Douglas Fir/Aspen Woodland	27
Upland Big Sagebrush Shrubland	26
High Elevation Grasslands	12
Hillside Fringed Sage and Grassland	0
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 48

Catchment Radius: 1 kilometer

Site Function: Food Processing Area



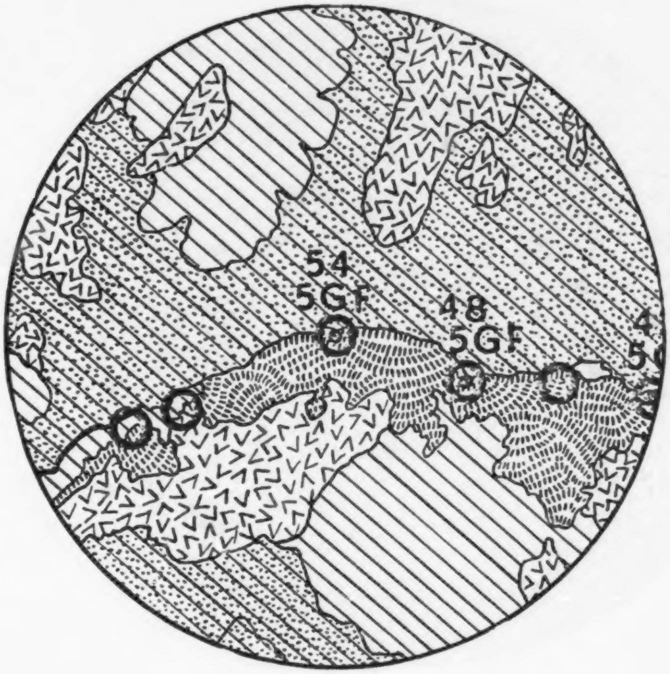
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	25
Douglas Fir/Aspen Woodland	20
Upland Big Sagebrush Shrubland	37
High Elevation Grasslands	12
Hillside Fringed Sage and Grassland	6
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 54

Catchment Radius: 1 kilometer

Site Function: Temporary Camp (2-3 Families)



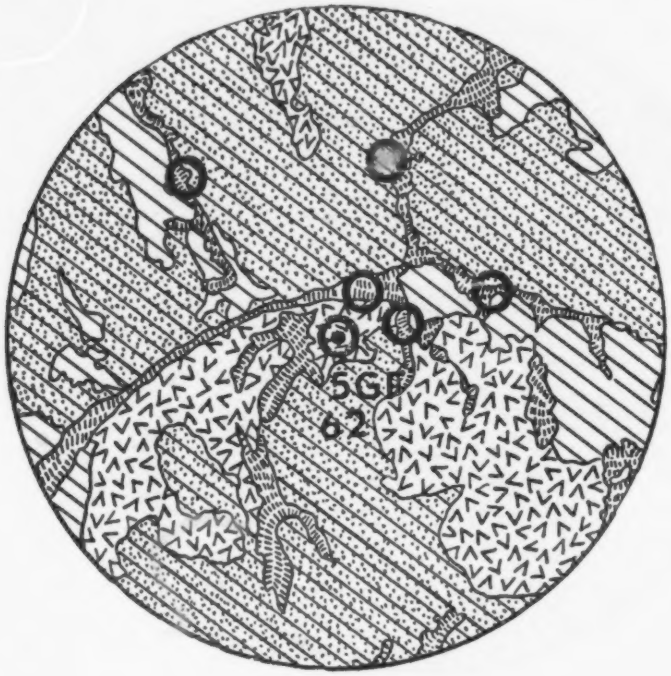
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	25
Douglas Fir/Aspen Woodland	31
Upland Big Sagebrush Shrubland	29
High Elevation Grasslands	0
Hillside Fringed Sage and Grassland	15
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 62

Catchment Radius: 1 kilometer

Site Function: Temporary Camp/Chipping Station



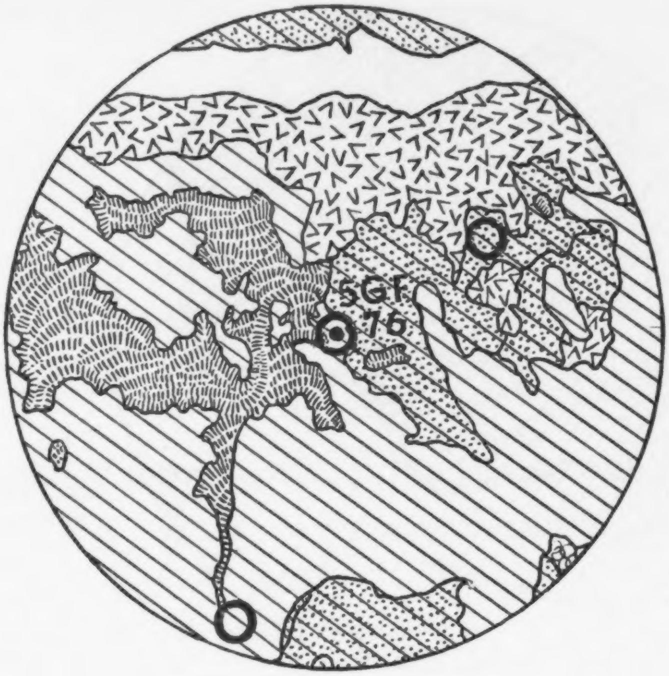
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	17
Douglas Fir/Aspen Woodland	24
Upland Big Sagebrush Shrubland	45
High Elevation Grasslands	0
Hillside Fringed Sage and Grassland	14
Bare Slope	0
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 76

Catchment Radius: 1 kilometer

Site Function: Two Camps and Food Processing Area



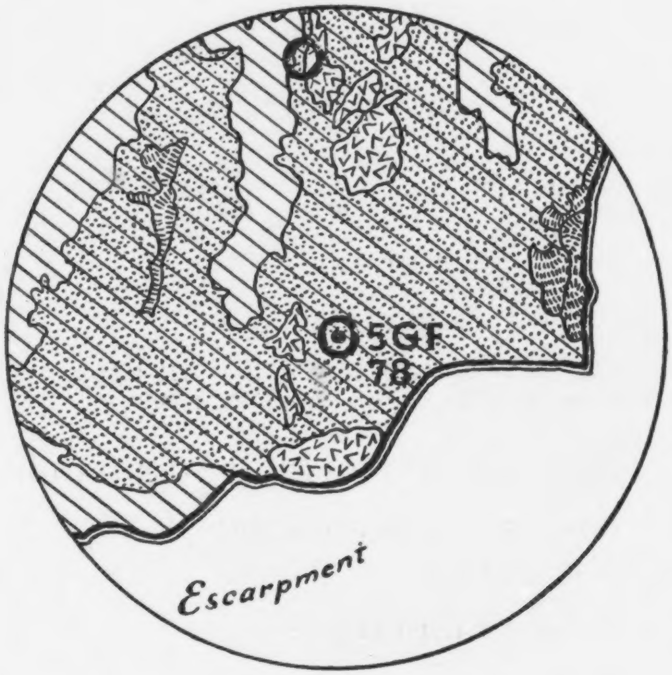
Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	49
Douglas Fir/Aspen Woodland	16
Upland Big Sagebrush Shrubland	5
High Elevation Grasslands	24
Hillside Fringed Sage and Grassland	0
Bare Slope	6
Boundary	0

NAVAL OIL SHALE RESERVE

Site Number 5GF 78

Catchment Radius: 1 kilometer

Site Function: Temporary Camp/Chipping Station



Vegetation Zone	Percentage of Cover
Mixed Mountain Shrubland	23
Douglas Fir/Aspen Woodland	5
Upland Big Sagebrush Shrubland	46
High Elevation Grasslands	3
Hillside Fringed Sage and Grassland	0
Bare Slope	0
Boundary	23

VEGETATION KEY (DUCK CREEK/CORRAL GULCH)

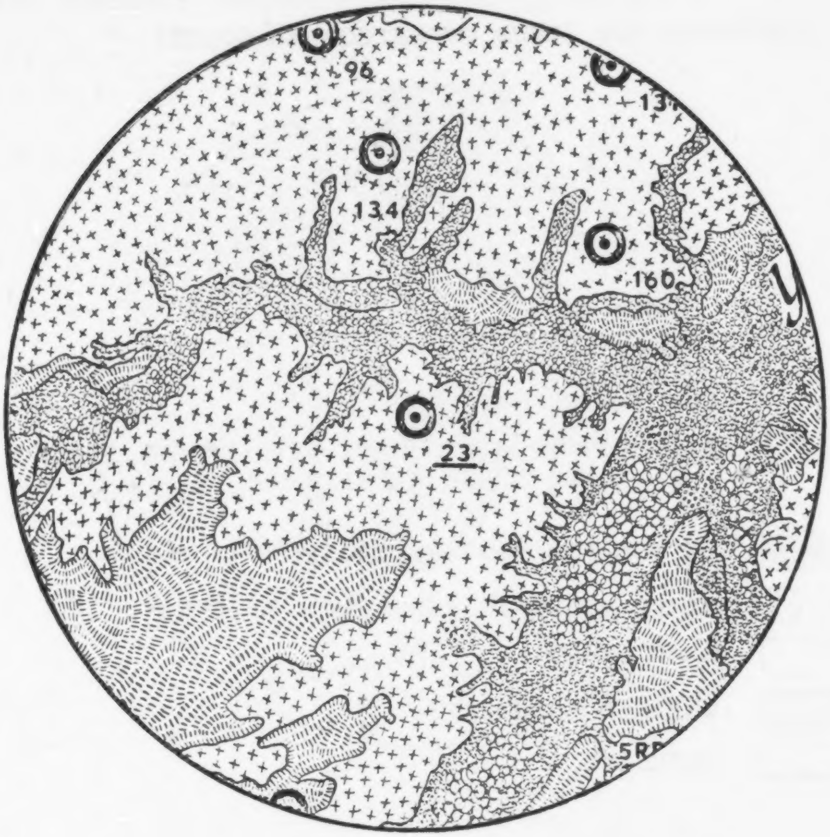
✢	PINON AND JUNIPER
⁙	CULTIVATED HAY
▒	MID-ELEVATION BIG SAGE WITH GRASS, BLACK SAGE AND SMALL RABBITBRUSH
▓	BOTTOMLAND BIG SAGEBRUSH/RABBITBRUSH
▧	MIXED MOUNTAIN SHRUBLAND
□	BARE SLOPE
▨	CHAINED LANDSCAPE
▭	BOUNDARY

DUCK CREEK REGION

Site Number 23 (D.U. Field #, see Olson et al. 1975)

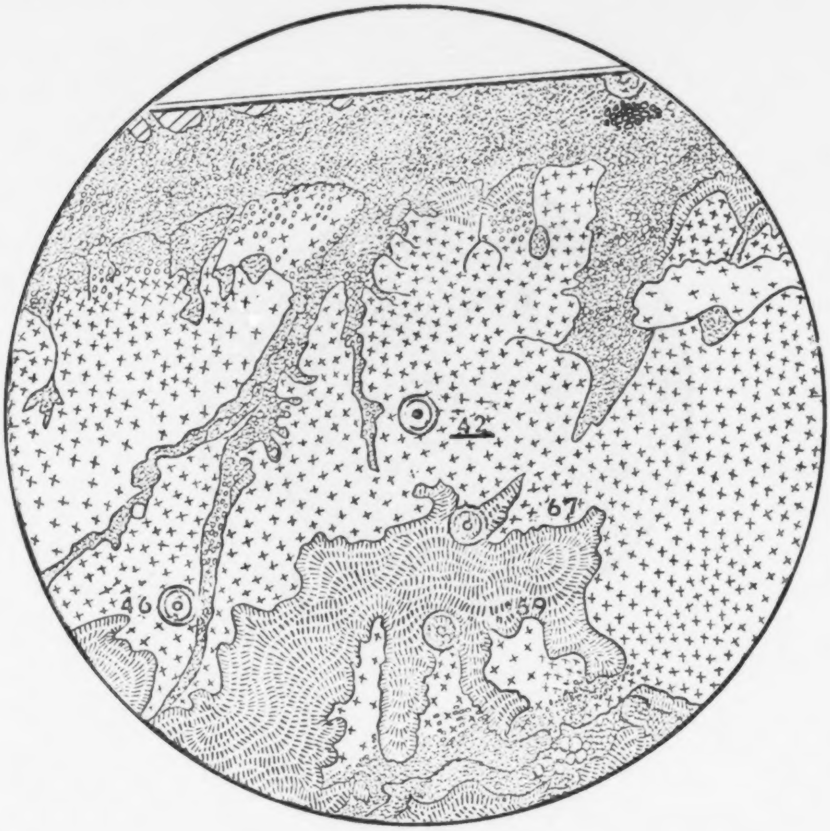
Catchment radius: 1 kilometer

Site Function: Lithic Scatter/Food Processing Area



Vegetation Zone	Percentage of Cover
Pinon/Juniper	49
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	20
Big Sage Brush (Bottomland)	31
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION
Site Number 42 (D.U. field #, see Olson et al. 1975)
Catchment radius: 1 kilometer
Site Function: Lithic Scatter



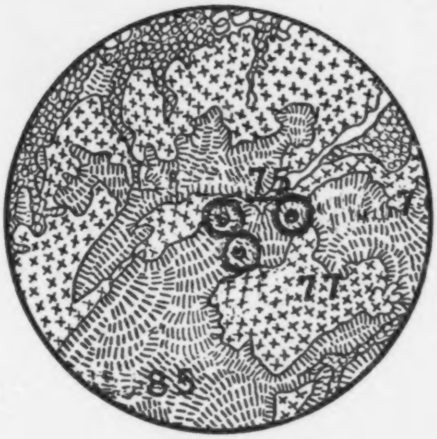
Vegetation Zone	Percentage of Cover
Pinon/Juniper	62
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	15
Big Sage Brush (Bottomland)	19
Mixed Mountain Shrubland	5
Boundary	0

DUCK CREEK REGION

Site Number 75 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Lithic Scatter



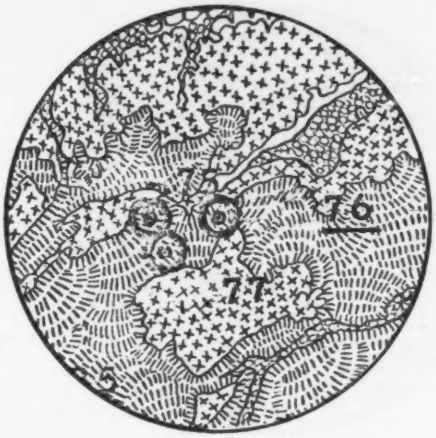
Vegetation Zone	**Percentage of Cover**
Pinon/Juniper	48
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	37
Big Sage Brush (Bottomland)	15
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 76 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Hide Processing Area



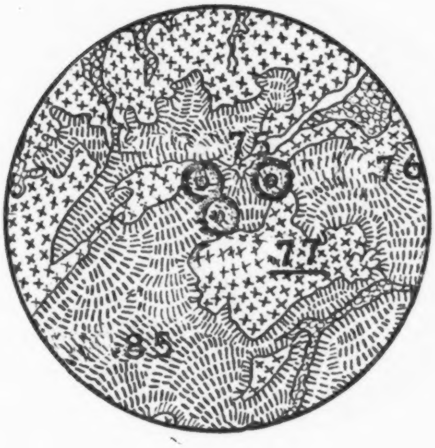
Vegetation Zone	Percentage of Cover
Pinon/Juniper	40
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	55
Big Sage Brush (Bottomland)	5
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 77 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Chipping Station



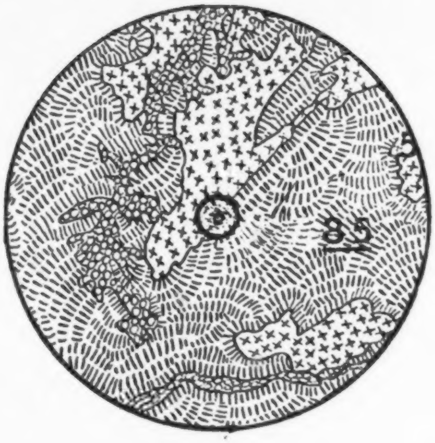
Vegetation Zone	Percentage of Cover
Pinon/Juniper	40
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	47
Big Sage Brush (Bottomland)	13
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 85 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Lithic Scatter



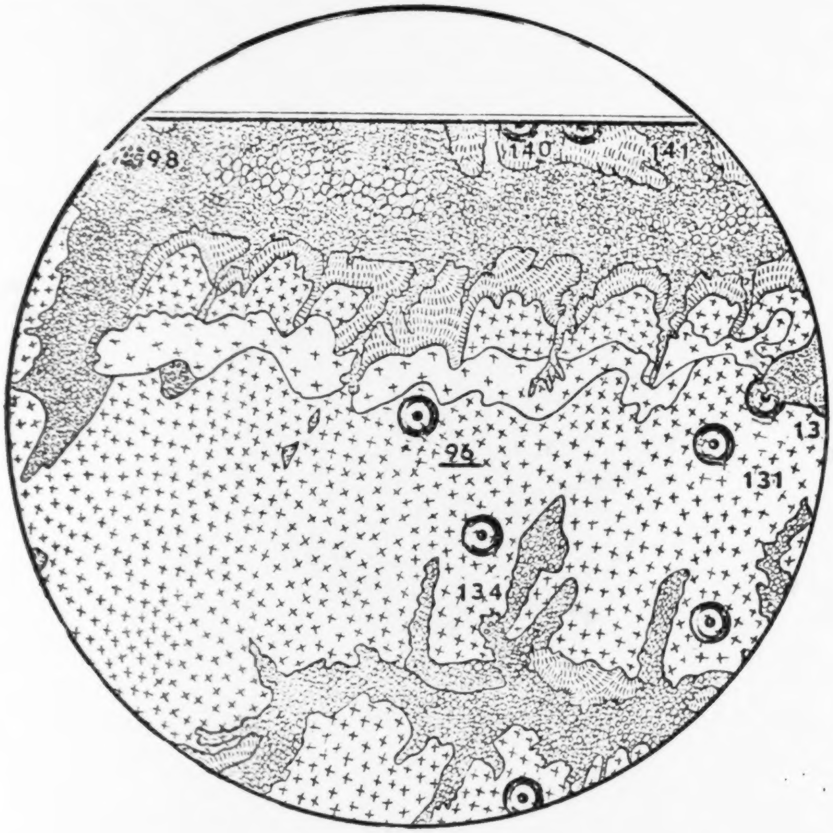
Vegetation Zone	Percentage of Cover
Pinon/Juniper	28
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	62
Big Sage Brush (Bottomland)	11
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 96 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Food Processing Area



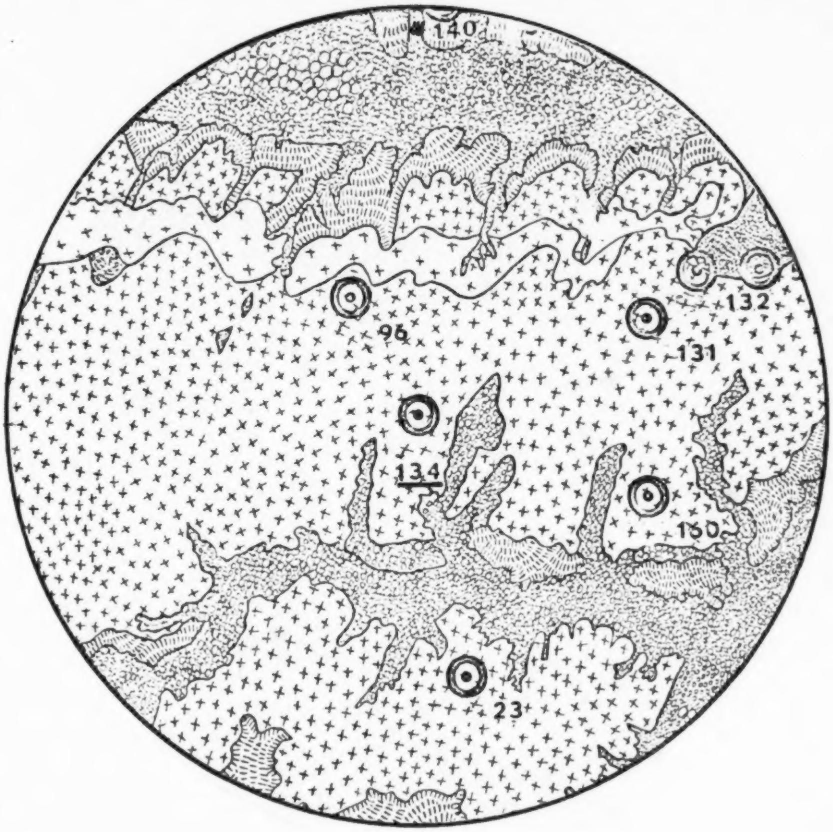
Vegetation Zone	Percentage of Cover
Pinon/Juniper	61
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	8
Big Sage Brush (Bottomland)	25
Mixed Mountain Shrubland	0
Boundary	6

DUCK CREEK REGION

Site Number 134 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Lithic Scatter



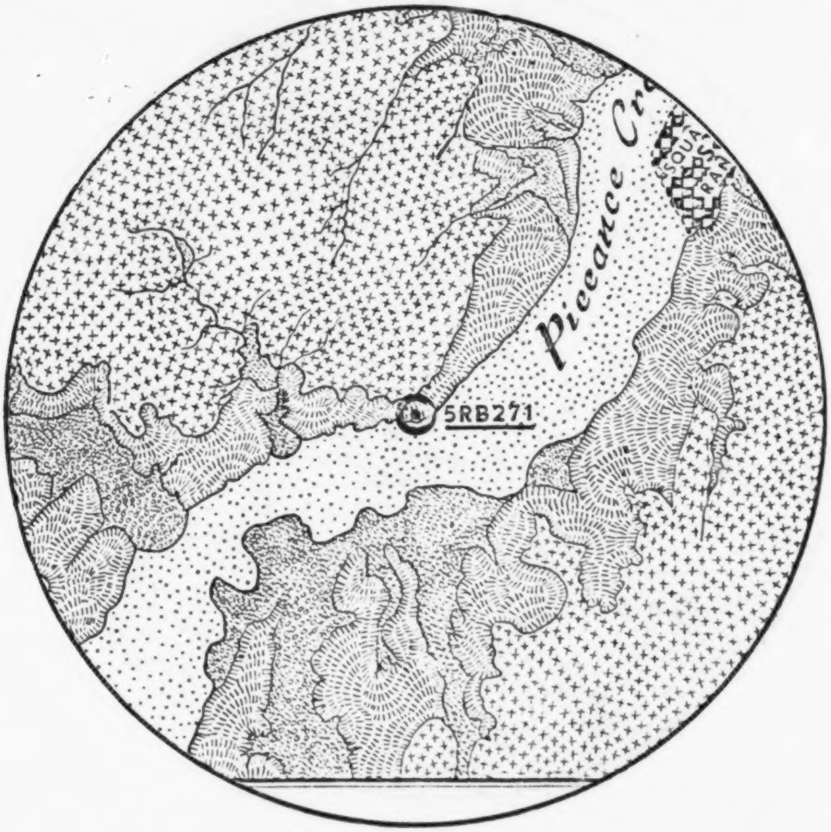
Vegetation Zone	Percentage of Cover
Pinon/Juniper	65
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	10
Big Sage Brush (Bottomland)	25
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 5RB 271

Catchment radius: 1 kilometer

Site Function: Habitation with Rock Art and Ancient Fields



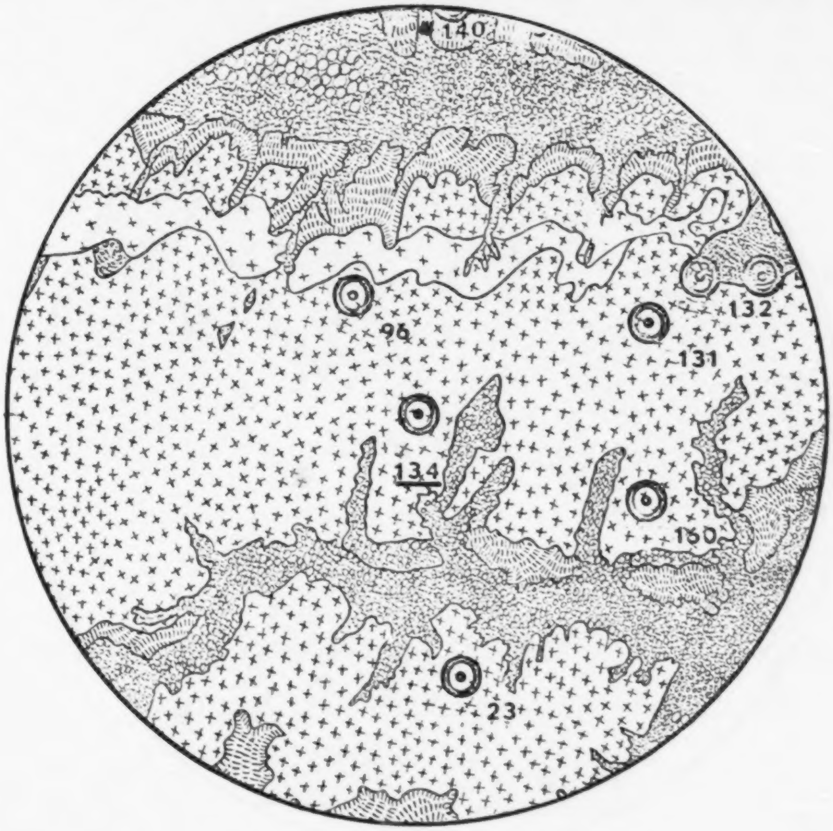
Vegetation Zone	Percentage of Cover
Pinon/Juniper	44
Cultivated Hay	15
Upland Big Sage/Mid Elevation Sagebrush	24
Big Sage Brush (Bottomland)	13
Mixed Mountain Shrubland	0
Boundary	2

DUCK CREEK REGION

Site Number 134 (D.U. field #, see Olson et al. 1975)

Catchment radius: 1 kilometer

Site Function: Lithic Scatter



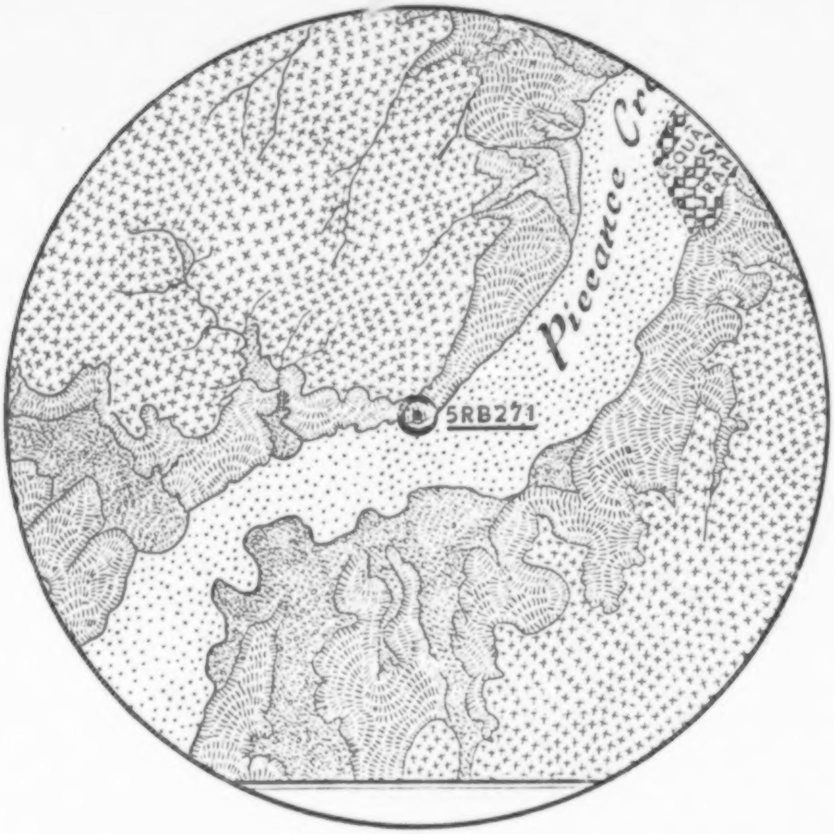
Vegetation Zone	Percentage of Cover
Pinon/Juniper	65
Cultivated Hay	0
Upland Big Sage/Mid Elevation Sagebrush	10
Big Sage Brush (Bottomland)	25
Mixed Mountain Shrubland	0
Boundary	0

DUCK CREEK REGION

Site Number 5RB 271

Catchment radius: 1 kilometer

Site Function: Habitation with Rock Art and Ancient Fields



Vegetation Zone	Percentage of Cover
Pinon/Juniper	44
Cultivated Hay	15
Upland Big Sage/Mid Elevation Sagebrush	24
Big Sage Brush (Bottomland)	13
Mixed Mountain Shrubland	0
Boundary	2

APPENDIX G

ARTIFACT INVENTORIES OF THE NAVAL OIL SHALE RESERVE AND THE DUCK CREEK/CORRAL GULCH AREAS

NAVAL OIL SHALE RESERVE ARTIFACT INVENTORY BY SITE

Site No. 5GF	Points		Scrapers		Util. Pcs.	Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.			Wh.	Fr.	Wh.	Fr.		
29		2	1		1	12				1		C.S.
30						110					1 Button	C.S.
31						11	1	1				C.S.
32						8					1 grinding stone frag.	S.S.C.
33						3		1		2	1 river cobble	T.S.C.
34						7	3	1				C.S./F.P.
35		1					1			1		F.P.
36						4					3 stones	Ch.St.
37						11		1	1			S.F.C.
38						4	2					S.F.C.
39	1								1			F.P.
40						6	1	1				S.F.C./W.A.
41						4	3				1 lapstone 2 misc. stones	C./W.A.
42		2				7						C.S.
43						12					1 hammerstone	T.C.(1)
44		1				7						T.C./Ch.St./(1)

NAVAL OIL SHALE RESERVE ARTIFACT INVENTORY BY SITE (continued)

Site No. 5GF	Points		Scrapers		Util. Pcs.	Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.			Wh.	Fr.	Wh.	Fr.		
45						10					1 hammerstone 2 river cobbles	T.C.(102)
46					1	5				1		T.C. (1)
47						13					2 cobbles	T.C.(sm grp)
48						2	5					F.P.
49						17		1				T.C.(1)
50					1		1				1 hammerstone	F.P./W.A.
51		1				21					1 knife	C./Ch.St.
52						12						Ch.St.
53		1				8	1			1		T.S.C.
54					2	6		1			2 cobbles	T.C.(2-3)
55						4						T.C./Ch.St.
56						13						T.C./Ch.St.
57						5						T.C./Ch.St.
58						15						T.C./Ch.St.
59	1					7						H.C.
60	1					13						T.C.
61						12						Ch.St.

NAVAL OIL SHALE RESERVE ARTIFACT INVENTORY BY SITE (continued)

Site No. 5GF	Points Wh.	Points Fr.	Scrapers Wh.	Scrapers Fr.	Util. Pcs.	Chps/ Flks.	Grinding Manos Wh.	Grinding Manos Fr.	Grinding Milling Wh.	Grinding Milling Fr.	Other	Site Function
62						4						T.C./Ch.St.
63						10						T.C./Ch.St.
64	1				1	27	22					S.B.C./F.P.
65	1						1	1			1 smooth pebble	F.P.
66						9						Ch.St./Sa.T.
67						7			1			F.P./Sa.T.
68		1				6	1				2 smooth stones 1 hammestone 1 knife	C./2-3 Ch.St.
69					1	2	1		1		2 cobbles	T.C./F.P.
70						3						T.C.
71						1					2 cores	F.P.?
72							2					F.P.
73	1				2	9	3	2		20	1 smooth pebble	3T.C./W.A.
74						11	1			1		2Ch.St./ W.A.
75						6						T.C./Ch.St.
76	3					24	5			5		2C./F.P.
77		2	1			18	1				3 cores	T.C./F.P.

NAVAL OIL SHALE RESERVE ARTIFACT INVENTORY BY SITE (continued)

Site No. 5GF	Points		Scrapers		Util. Pcs.	Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.			Wh.	Fr.	Wh.	Fr.		
78						5						T.C./Ch.St.
79						4	4				2 cores	T.C./F.P.
80						1	1					F.P.
81						26	6	2			10 cores, 1 blade fr.	C./F.P.
82						2		1	1			F.P.
83							2				1 polished stone 1 core	F.P.
84							4					F.P.
85						5	5		1	4	1 blade, 1 core	T.C./F.P.
86	1		1			8			1			T.C./F.P.
87									4	2		F.P.
88			2			10	5		1		1 cobble	F.P.
89		1	2			15	2				3 cores 1 smooth stone	2C./F.P.
90						4	3			1	2 cores	2C.
91						3					2 cores	T.C./Ch.St.
92	3		1				2	1			1 drill fragment 1 pebble 4 cobbles (broken)	C.

NAVAL OIL SHALE RESERVE ARTIFACT INVENTORY BY SITE (continued)

Site No. 5GF	Points		Scrapers		Util. Pcs.	Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.			Wh.	Fr.	Wh.	Fr.		
93						1			1	1		F.P.
94		2				8					1 core	Ch.St.
95		2				9						Ch.St.
96	1	1				13					2 blades	L.S.
97			1			20					1 potsherd, 3 cores	T.C.
98	1					4			1			T.C.
99						3			1			F.P.
100								1	1			F.P.
101						10	2	1			3 cores	Ch.St.
102	2					25					1 polished stone 1 resin ball	Ch.St.
103							3			2		F.P.
104							2		1			F.P.

T.C. = Temporary Camp
C. = Camp
S.F.C. = Single family camp
C.S. = campsite
T.S.C. = Temporary summer camp
Sa.T. = Satellite site
(#) = Number of families

L.S. = Lithic scatter
Ch.St. = Chipping station
W.A. = Work area
F.P. = Food processing
H.C. = Hunter's camp
S.B.C. = Summer base camp
S.S.C. = Small summer camp

DUCK CREEK/CORRAL GULCH ARTIFACT INVENTORY BY SITE

D.U. Field No.	Points Wh.	Points Fr.	Scrapers Wh.	Scrapers Fr.	Knives Wh.	Knives Fr.	Chps/ Flks.	Grinding Manos Wh.	Grinding Manos Fr.	Grinding Milling Wh.	Grinding Milling Fr.	Other	Site Function
17		1		3		3	6						L.S.
18	1												C.
22							9						L.S.
23		4	3			4			1				L.S./F.P.
26	1			2		2	1				1		L.S.
48	1						2						L.S.
49		1					3						L.S.
56							1						L.S.
57		2	5		3		63					1 drill, pottery	B.C.
58							3					1 potsherd	C.
59									1				F.P.
60									1				F.P.
61								1					F.P.
62				1			2						H.P.
63							2						L.S.
68				2	1		9						H.P.
69							1						L.S.
73		1					2	1					F.P.

DUCK CREEK/CORRAL GULCH ARTIFACT INVENTORY BY SITE (continued)

D.U. Field No.	Points Wh.	Points Fr.	Scrapers Wh.	Scrapers Fr.	Knives Wh.	Knives Fr.	Chps/ Flks.	Grinding Manos Wh.	Grinding Manos Fr.	Grinding Milling Wh.	Grinding Milling Fr.	Other	Site Function
74		1	3				7		2			1 chopper	Ch.St./L.S./ F.P.
75							3						L.S.
76				1									H.P.
77												1 toolstone	Ch.St.
78		1		1			5						L.S./H.P.
79				1									L.S./H.P.
80		1	4			1	25		1			1 toolstone	L.S./F.P.
85				4		3	99						L.S.
86		1	1			3						pottery, toolstone	C.
91							1						L.S.
92			1				2						L.S./H.P.
93												wickiup toolstone	Ute Habitation/B.C.
96									1				F.P.
98							1					1 maul	L.S.
99									1				F.P.
105				1			1						L.S./H.P.

DUCK CREEK/CORRAL GULCH ARTIFACT INVENTORY BY SITE (continued)

D.U. Field No.	Points		Scrapers		Knives		Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.	Wh.	Fr.		Wh.	Fr.	Wh.	Fr.		
108							4						L.S.
114							6						L.S.
115		1	6		1		135		3	1		toolstone, pottery, bone	B.C./H.P./ F.P.
116	2		1				13	1				1 toolstone	L.S./H.P.
118				1		4	25		1				L.S./H.P./ F.P.
119		1					11					1 toolstone	Ch.St.
120							2						L.S.
123			4				17		2			1 core, 1 toolstone, bone	H.P./Ch.St./ F.P.
124	1						74						L.S./Ch.St.
125			1				8						L.S./H.P.
126							1						L.S.
127			1				2						L.S./H.P.
128			1				13		1			1 hammerstone, 1 toolstone	F.P./H.P.
130									1(2 pieces)				F.P.
131									1				F.P.

DUCK CREEK/CORRAL GULCH ARTIFACT INVENTORY BY SITE (continued)

D.U. Field No.	Points		Scrapers		Knives		Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.	Wh.	Fr.		Wh.	Fr.	Wh.	Fr.		
132				1		1	14						L.S./H.P.
133									1				F.P.
134							5						L.S.
135							1						L.S.
138		1				1	2		1				F.P.
139			1			1	49						L.S.
140	4	4				3	90	1	4			toolstone, drill, 5 tool fragments, wickiup	B.C./Ute/ Fremont Occupation
141		1	2			1	7						L.S./H.P.
143				1			1						L.S./H.P.
145		1		3		1	28					wickiup	B.C./H.P./ F.P.
146		1	1			1	35					2 wickiups, 16 trade beads	B.C./Late Ute
147			3			1							H.P.
148		2				2	52					1 gray sandstone bead	L.S.
152	1		1				13	1				1 hammerstone, 1 HS fragment	F.P.

DUCK CREEK/CORRAL GULCH ARTIFACT INVENTORY BY SITE (continued)

D.U. Field No.	Points		Scrapers		Knives		Chps/ Flks.	Grinding Manos		Grinding Milling		Other	Site Function
	Wh.	Fr.	Wh.	Fr.	Wh.	Fr.		Wh.	Fr.	Wh.	Fr.		
153		1	6			6	51		1				L.S./F.P.
159			4				9		2			hammerstone	H.P./F.P./ B.C.
164		2		1		3	12		4			hammerstone, chopper	F.P./H.P.
170							1						L.S.
5RB 271*							2	1				rockart panels/ ancient fields	Habitation

*Excavated by Grady. See Appendix H.

Presence of scrapers and knives = hidc preparation = H.P.
Presence of manos and/or crushing stones = food preparation = F.P.
Lithic scatter = L.S.
Chipping stations baseed on presence of foreign stone, i.e. toolstone = Ch.St.
Base camp = B.C.

APPENDIX H

REPORT OF TEST EXCAVATIONS OF THE SQUARE S ROCKSHELTER (5RB-271), CONDUCTED IN AUGUST 1976

The site is located in T.1 S., R.97W., SW¼ SW¼ of Section 15. It is situated on B.L.M. land some 975 meters southwest of the Square S Ranch house and 500 meters NNE of Bench Mark 6053 (located T.1 S., K.97W., Sec. 22). Map reference U.S.G.S. square S quad dated 1952. Estimated elevation of the site is 6100 feet. The site is on the west side of Piceance Creek and faces to the southeast.

This portion of Piceance Creek is a broad, flat valley with moderate to high alkalinity in the surface soils. Where levels of both alkalinity and salinity are low in surface soils, rabbit brush (Chrysothamnus nauseousus) and big sage (Artemisia tridentata) tend to form important communities. These communities usually form in valley mouths emptying into the Piceance flood plain where leaching tends to keep alkalinity and salinity build-up low. Greasewood (Sarcabatus vermiculatus) communities are found on stream edges with the shrubs ranging from 1.5-2.0 meters tall. In the open flat portions of the Piceance Creek flood plain adjacent to the site, rye grass (Lolium perenne L.) and alfalfa (Medicago sativa L.) are cropped as hay.

The slopes immediately adjoining the site are covered with juniper (Juniperus osteosperma (Torr.) little), while the ridge tops are covered with a mixture of pinon pine (Pinus edulis) and juniper.

There is permanent running water within 20 meters of the site (Piceance Creek).

The site can be divided into three areas:

a. The rock shelter itself.

b. The rock face some 30 meters to the southwest that exhibits trapazoidal paintings usually diagnosed as belonging to the Fremont culture.

c. An area approximately 150 meters to the SSE of the rock shelter on the flood plain that shows evidence (visible on aerial photography only) of aboriginal fields.

All work was restricted to the rock shelter proper. The rock shelter is 26.82 meters wide (87.99 feet) and 7.16 meters (23 feet 6 inches) deep. Approximately one third of the total area of the shelter exhibits evidence of occupation. The rest shows evidence of recent formation and rock fall.

The site has suffered extensive damage since the Anglo occupation of the valley. The first event seems to have been the construction of a rather narrow road on the west side of Piceance Creek. The road, probably cut into the talus slope in front of the site with the use of a fresno is shown on the 1883 survey plot by John B. Moore, filed in Denver in 1884. Since this is the first survey of the area and the road is already indicated, destruction of the archaeological integrity of the site started early. Since 1884 the Piceance Creek road has been moved to the opposite side of the valley. Traces of the old road still exist. In the last several years a new road has been bulldozed through the site along with a pipeline.

As a result large portions have been lost due to construction; the remainder has been extensively potholed by looters.

Most sites in the Piceance Basin can only be described as "veneer sites," sites with a thin surface scatter of flakes and artifacts. The cut left by the bulldozer clearly indicated that the Square S rock shelter is one of the few sites in the region that shows any appreciable depth. Consequently, it offered the possibility of recovering:

a. Cultural sequences, the Fremont/Ute interface is not well known in NW Colorado.

b. Environmental data, recovery of evidence of climatic change or stability would be of inestimable value in understanding the cultural dynamics of the region.

The site was mapped, baseline and datum point established (see Fig. 22). A grid was established based on six foot squares. It was necessary to shift to feet and inches since most of the volunteer workers were not overly familiar with the metric system. The squares

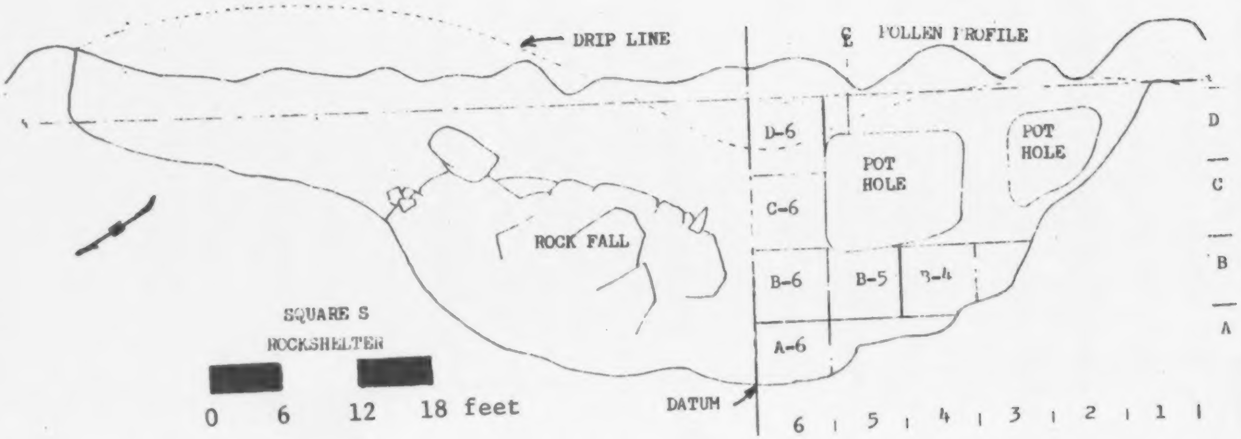

DRIP LINE
℄ POLLEN PROFILE
D-6
C-6
B-6
A-6
B-5
B-4
POT HOLE
POT HOLE
ROCK FALL
D
C
B
A
6
5
4
3
2
1
DATUM
SQUARE S ROCKSHELTER
0 6 12 18 feet

FIGURE 22

PLAN OF THE SQUARE S ROCKSHELTER 5RB-271,
PICEANCE BASIN, COLORADO

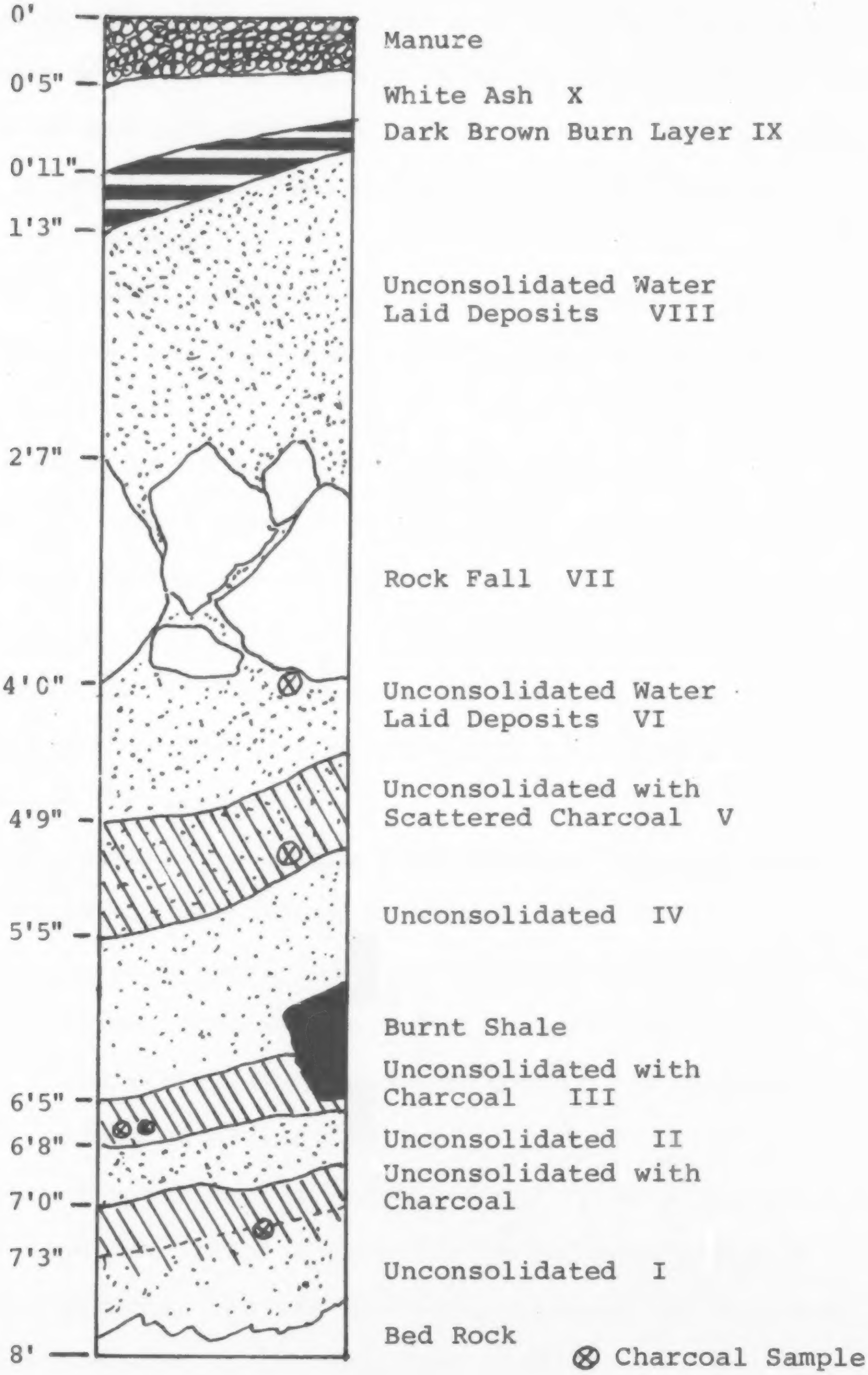

0'
0'5"
0'11"
1'3"
2'7"
4'0"
4'9"
5'5"
6'5"
6'8"
7'0"
7'3"
8'
Manure
White Ash X
Dark Brown Burn Layer IX
Unconsolidated Water Laid Deposits VIII
Rock Fall VII
Unconsolidated Water Laid Deposits VI
Unconsolidated with Scattered Charcoal V
Unconsolidated IV
Burnt Shale
Unconsolidated with Charcoal III
Unconsolidated II
Unconsolidated with Charcoal
Unconsolidated I
Bed Rock
⊗ Charcoal Sample

FIGURE 23

STRATIGRAPHIC PROFILE SQUARE S ROCKSHELTER 5RB-271
PICEANCE BASIN, COLORADO

were numbered from south to north and alphabetic designations were used from west to east.

Squares B6, C6, D6, and B4 were chosen for excavation, B5 was retained intact for future work. Excavation was based on 4 inch levels, but once layering was established we switched to natural stratigraphy. Two persons were assigned to each square with a third person designated as recorder.

In addition to the four squares chosen for excavation, a verticle profile was cut and dressed in the front of the shelter to establish soil sequences within the shelter.

Square B6 quickly proved to be sterile and was abandoned when contact was made with bedrock within the first four inches.

Square C6 yielded segmented fecal material tentatively identified as belonging to mountain sheep. Burned greasewood was also recovered.

Square D6 produced some unidentified burned bone.

Square B4 consisted of a complex 39 inches deep to bedrock of a variety of different colored ash and soil layers. Extensive amounts of pack rat nests and burned bone (rib of elk?) were recovered. Large amounts of burned bone fragments, juniper berries were found, and two flakes were also recovered.

Pollen profile. Total exposure from surface to bedrock was exactly 8 feet (2.47 meters). Within this eight foot exposure ten layers were discernible and in five alternative layers starting immediately above bedrock, charcoal was present. Soil samples were taken from each layer and charcoal was taken from the five layers where found (see Fig. 23).

Because of the tremendous amount of damage done to the rock shelter by road, pipeline construction, and potholing, the artifact returns are minimal (two flakes) and consequently no portion of the rock shelter can be assigned any cultural affiliation. However, the presence of Fremont rock art in the immediate area and the possibility of the presence of aboriginal fields would argue for occupation as early as the Fremont, and continuing up to the historic period.

APPENDIX I

GLOSSARY

Aspect

The direction in which a slope faces, its down hill orientation expressed as a compass heading.

Density, Vegetation

The number of individual plants per unit of space. It can vary because of a plant's tendency to clump or cluster, consequently figures used are averages for those particular zones.

Productivity Area Index

An index derived by multiplying the percentage of cover of a given vegetation type by its net primary production (NPP) per day.

Productivity, Vegetation

Defined as the rate at which energy is stored by photosynthesis and chemosynthesis in the form of organic substances which can be used as food materials. There are two kinds of primary productivity:

Gross Primary Productivity (GPP) which is the total rate of photosynthesis, and

Net Primary Productivity (NPP) which is the rate of storage of organic matter in excess of the respiratory requirements of the plant.

Site Catchment

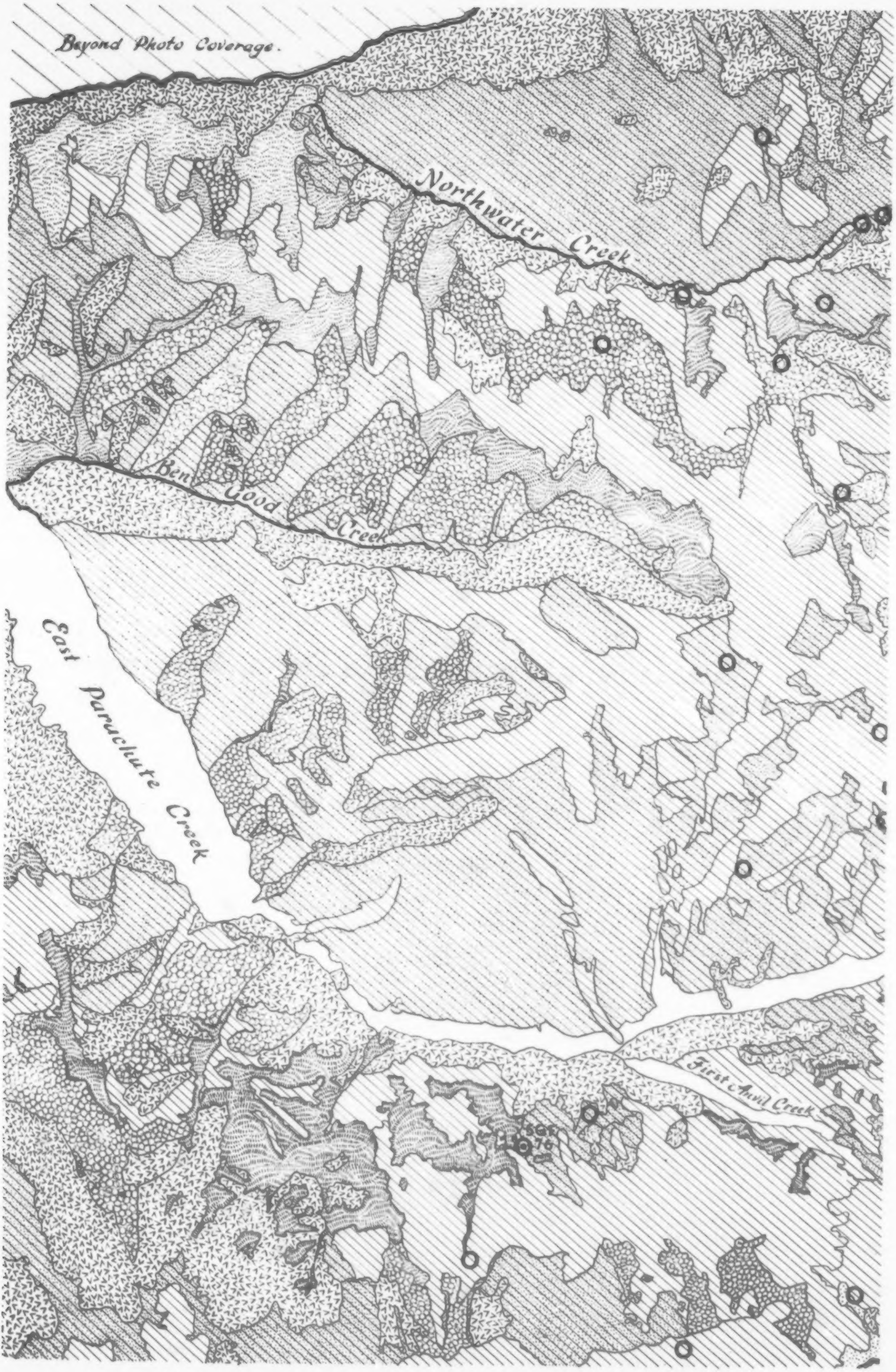
Refers to the area surrounding an archaeological site and from which it is reasonable to assume the site drew sustenance. In this study a radius of 1 (one) kilometer has been used to define this area.

Slope

The downward slant from the horizon of the land surface.

APPENDIX J

VEGETATION MAPS DERIVED FROM AERIAL PHOTOGRAPHY


Beyond Photo Coverage.
Northwater Creek
Ben Good Creek
East Parachute Creek
First Anvil Creek

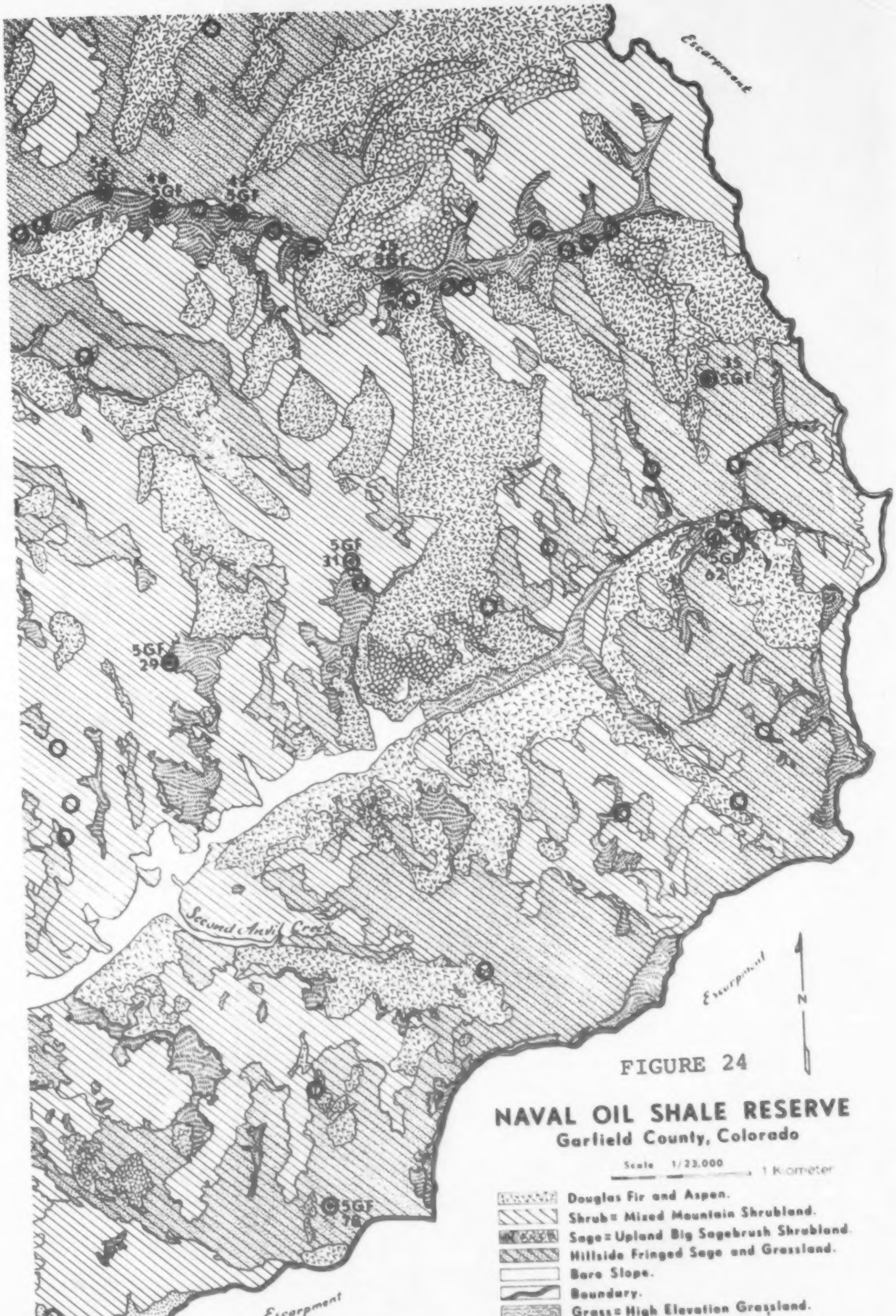


FIGURE 24

NAVAL OIL SHALE RESERVE
Garfield County, Colorado

Escarpment
Escarpment
Escarpment
Second Anvil Creek
N
54 5GF
48 5GF
47 5GF
45 5GF
35 5GF
5GF 31
5GF 29
5GF 62
5GF 78
Scale 1/23,000 1 Kilometer
Douglas Fir and Aspen.
Shrub = Mixed Mountain Shrubland.
Sage = Upland Big Sagebrush Shrubland.
Hillside Fringed Sage and Grassland.
Bare Slope.
Boundary.
Grass = High Elevation Grassland.
5GF Sites chosen for catchment analysis.
Other Archaeological Sites.

site distribution after Kane 1973

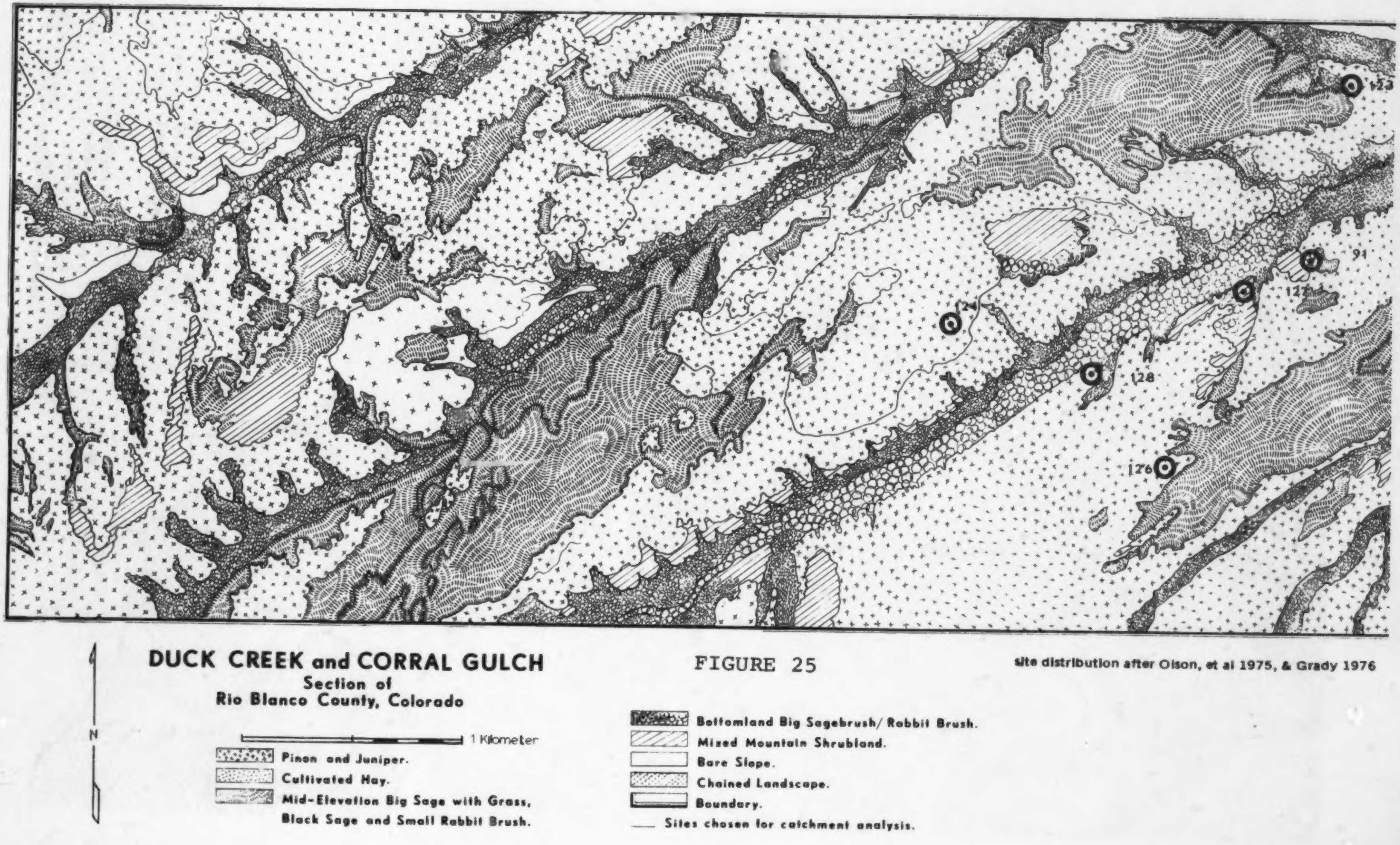
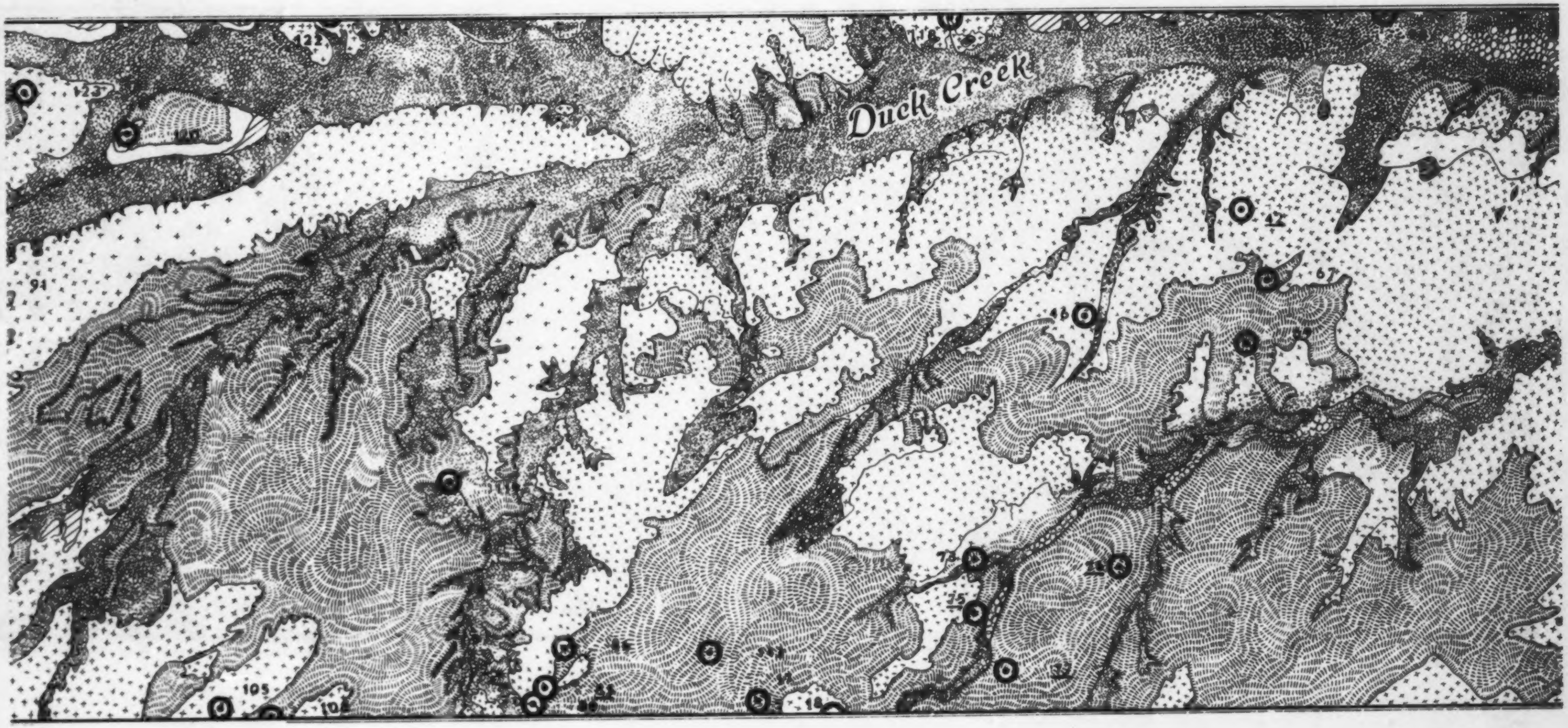
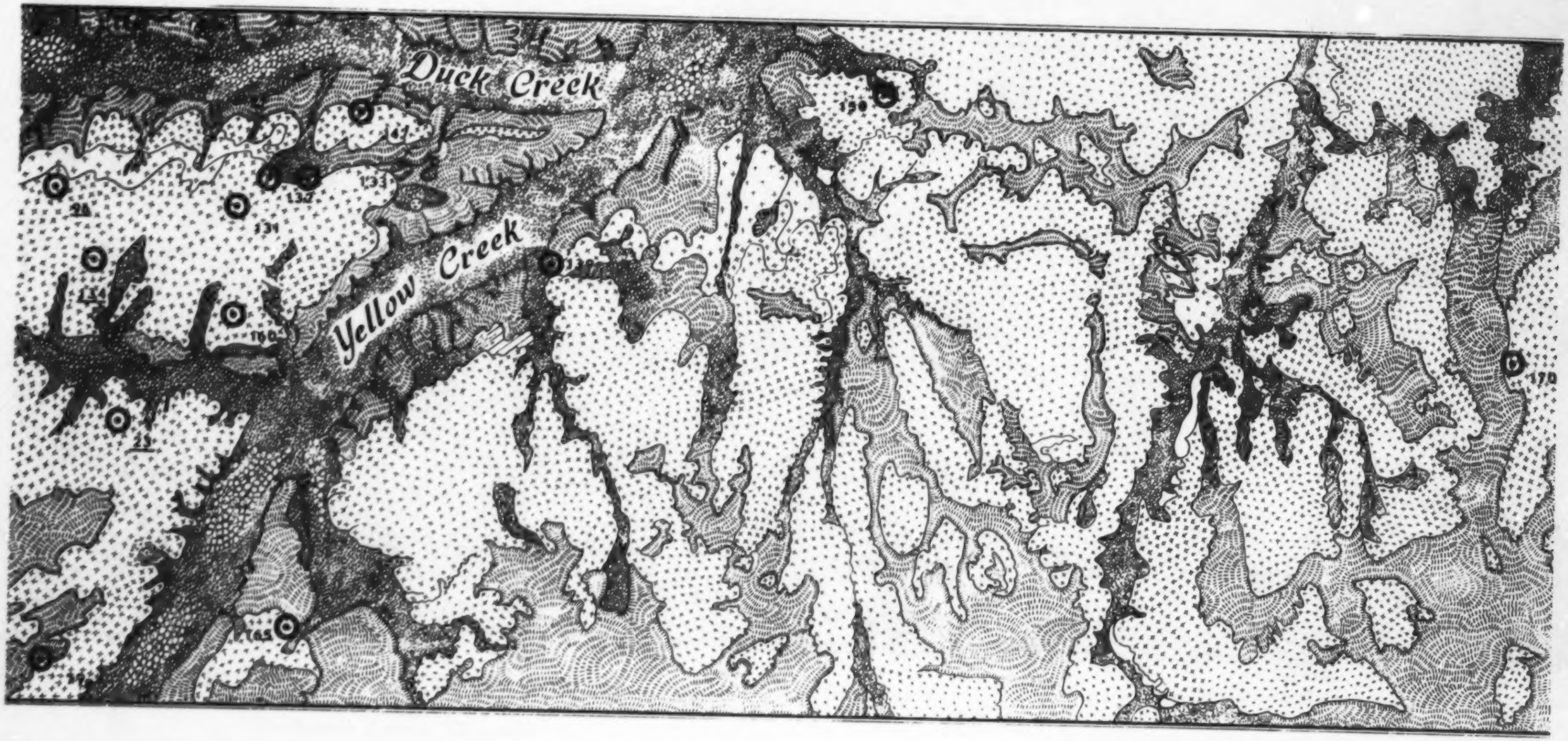

123
91
127
124
128
176
N
1 Kilometer
Pinon and Juniper.
Cultivated Hay.
Mid-Elevation Big Sage with Grass, Black Sage and Small Rabbit Brush.
Bottomland Big Sagebrush/ Rabbit Brush.
Mixed Mountain Shrubland.
Bare Slope.
Chained Landscape.
Boundary.
Sites chosen for catchment analysis.

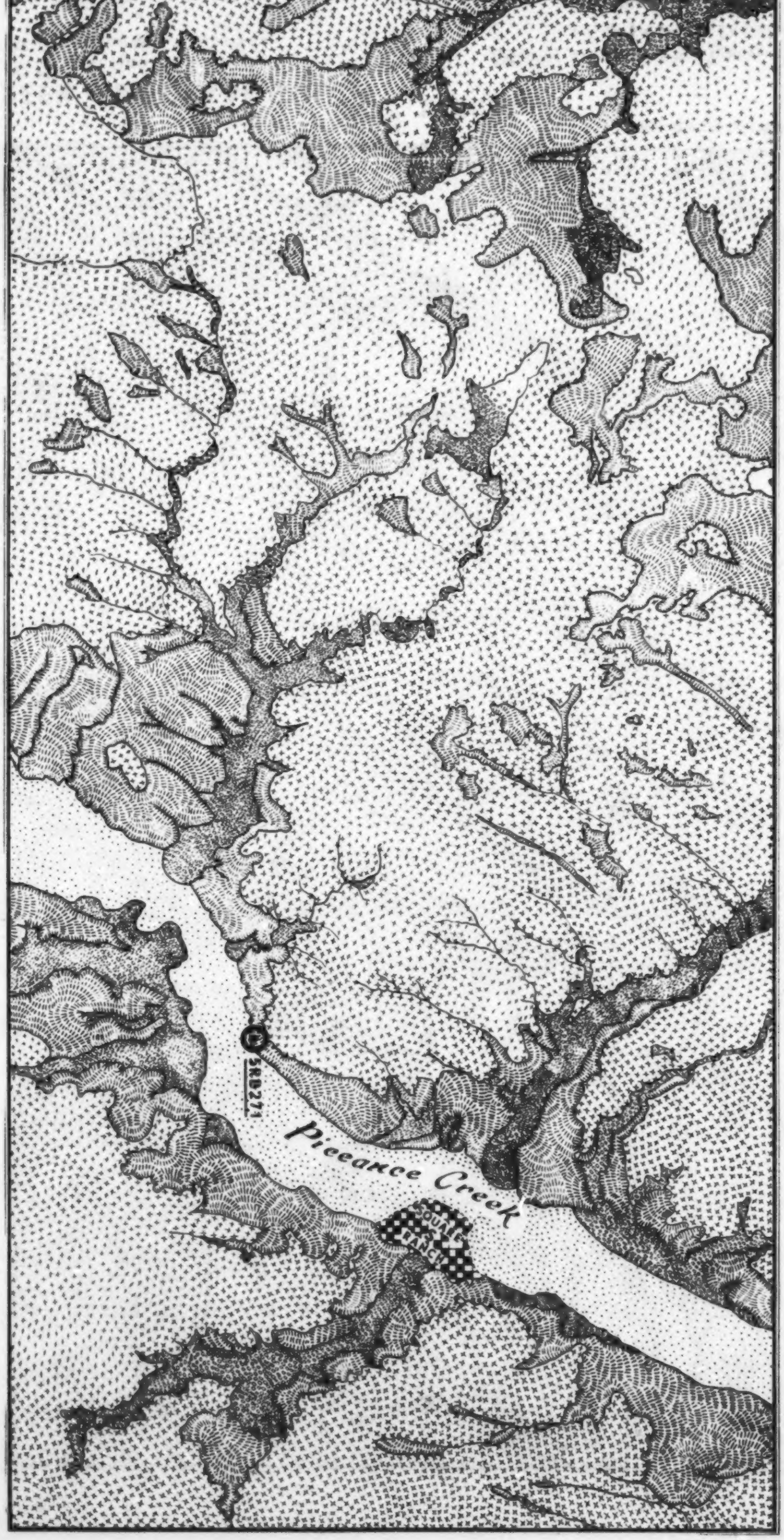
FIGURE 25

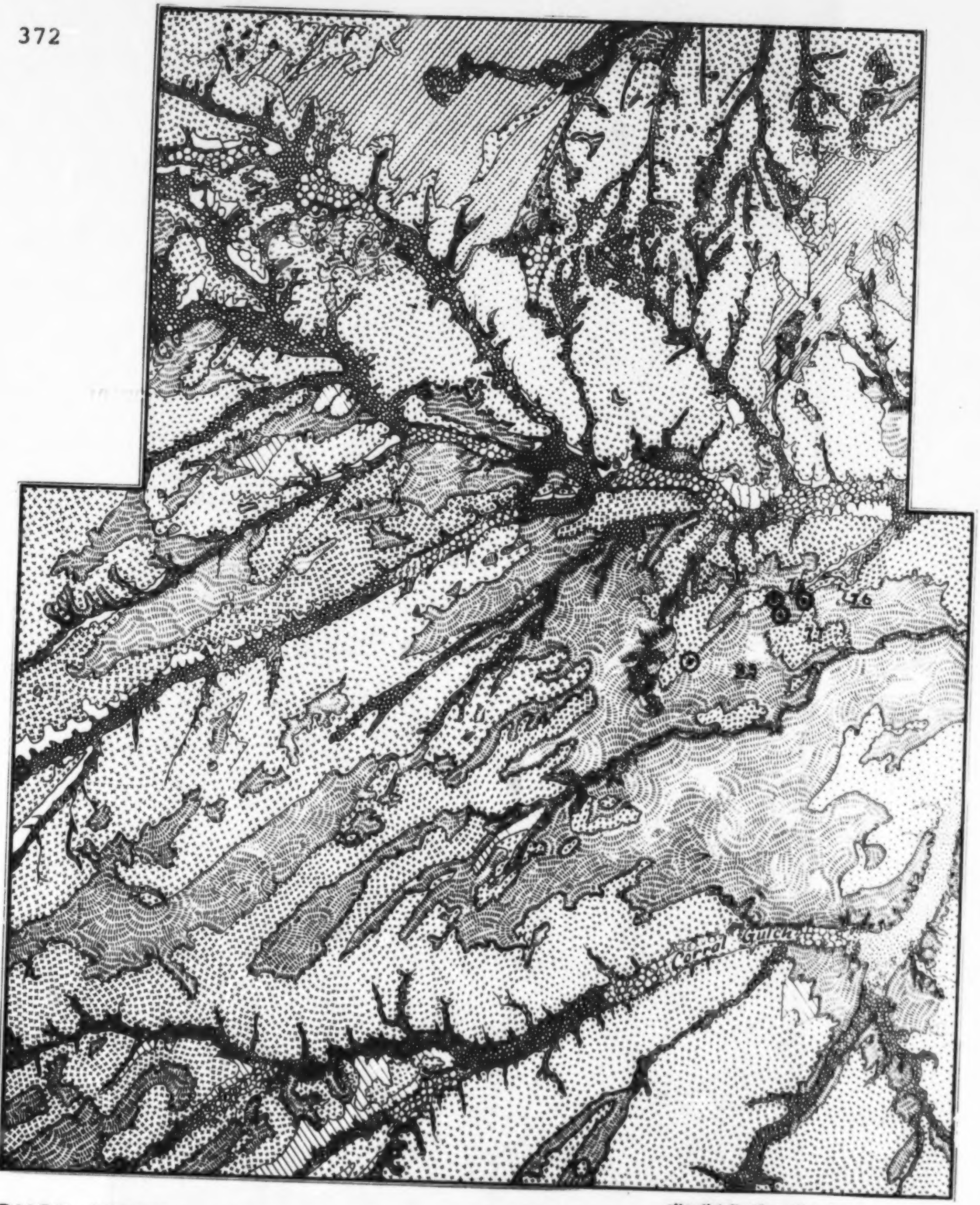
DUCK CREEK and CORRAL GULCH
Section of
Rio Blanco County, Colorado

site distribution after Olson, et al 1975, & Grady 1976


Duck Creek
122
123
120
118
91
42
67
46
73
75
32
105
104
18


Duck Creek
Yellow Creek
190
147
133
132
131
160
170
165


170
5RB271
Piceance Creek
South Ranch



site distribution after Olson, et al 1975

DUCK CREEK and CORRAL GULCH

Section of
Rio Blanco County, Colorado

FIGURE 26

N

1 Kilometer

- ▨ Pinon and Juniper.
- ▨ Cultivated Hay.
- ▨ Mid-Elevation Big Sage with Grass, Black Sage and Small Rabbit Brush.
- ■ Bottomland Big Sagebrush/Rabbit Brush.
- ▧ Mixed Mountain Shrubland.
- ☐ Bare Slope.
- ▨ Chained Landscape.
- ☐ Boundary.
- — Sites chosen for catchment analysis.

James Grady was born in Cleveland, Ohio, and has lived on and off in the West since 1961. He attended the Municipal University of Omaha, now the University of Nebraska-Omaha, where he received his Bachelor's degree in Sociology (Anthropology); the University of Colorado, Boulder, where he received both his M.A. and Ph.D. in Anthropology; and Cambridge University, England, where he received a Certificate in Prehistoric Archaeology. An expert in the fields of aerial photographic interpretation and remote sensing, he has been involved in the aerial mapping of the Maya city of Copan in Honduras. He has also served as a consultant, specializing in sampling strategy design and ecological modeling, to various cultural resource management firms in the Rocky Mountain area. In addition, he has held teaching positions at The Colorado College, the University of Wyoming, the University of Denver, the University of Colorado, and is currently a Visiting Assistant Professor at the University of Nebraska-Lincoln as well as holding an Adjunct Assistant Professorship at the University of Denver.

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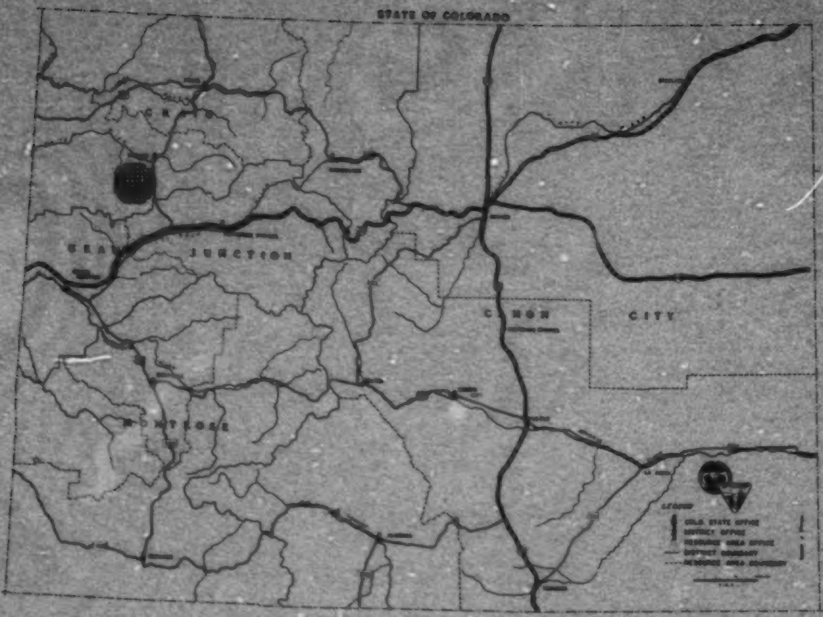
STATE OF COLORADO
CRAIG
GRAND JUNCTION
CANON CITY
MONTROSE
LEGEND
COLO. STATE OFFICE
DISTRICT OFFICE
RESOURCE AREA OFFICE
DISTRICT BOUNDARY
RESOURCE AREA BOUNDARY